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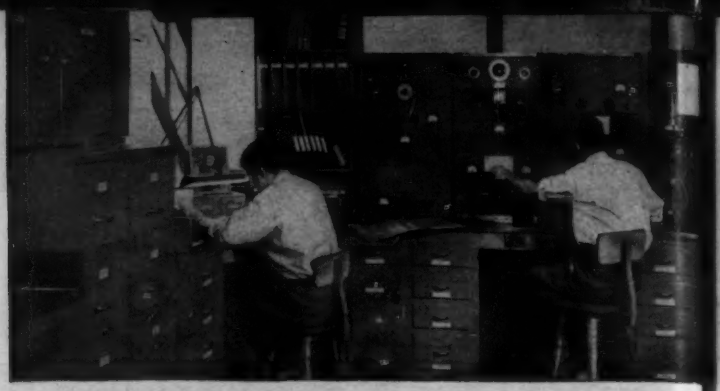

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The Economic Reconstruction of Europe

THE time is fast approaching when allied and enemy populations alike will demand a blueprint for the economic reconstruction of Europe. The peace plans following this World War will be written piecemeal, and by experts, at a series of continuing conferences, such as Hot Springs, Bretton Woods, Dumbarton Oaks and Quebec, each tracing a new pattern for negotiation and each dealing with a single, specific problem. In the drawing of these plans, the United States, as owner of more than half of the world's industrial capacity, controller of the only great credit reservoir, and possessor of the largest force of highly skilled technicians and management engineers, has heavy responsibilities which its industrial, financial, agricultural and labor leaders cannot evade.

☆ ☆ ☆

Just what is the problem which the world's business leaders must help solve in Europe?

The best safeguard of peace is economic opportunity—a good chance for all peoples to raise their standard of living by their own ingenuity, foresight and industry.

Frustrated and disappointed peoples, who view the future with misgiving rather than hope, breed fanatical demagogues who seek to divert nations from their ills and disappointments by promising military glory and conquests.

Consequently, an important step in building a secure and lasting peace is to open the doors of opportunity to the peoples of Europe.

The greatest obstacle to opportunity in Europe has been economic nationalism.

The economic tradition of the Continent always has been highly nationalistic. The national feeling generated by the first World War, and the political autonomy conferred upon many peoples by the peace treaties, led to a great growth of economic restrictions. This trend was accentuated by the depression and by the military plans of the Fascists and Nazis. Hitler had to show his people they could be fed even if a blockade was imposed again. The inevitable result of these influences was to carry self-sufficiency to tragic extremes.

Economic nationalism holds down the standard of living of Europe in two ways:

1. It prevents the rise in most European countries of low-cost mass production.
2. It operates against an efficient geographical division of labor, preventing nations from doing what each can do best.

Great machines require great markets. One great machine of which the United States has many and Europe few is the continuous strip steel mill. At the outbreak of the war we had twenty-eight such mills of various sizes, England but one, and Continental Europe one. A building containing one of these machines is more than a quarter of a mile long and the minimum cost of the mill is almost $25,000,000. Only the prospect of a mass market justifies production on this vast, but highly economic basis.

The wasteful geographical distribution of production is shown by the agricultural policies of Italy, France and Germany.

In the 1930's, when lard sold for less than 8¢ a lb. in the United States, it cost 32¢ a lb. in Germany. In Italy and Germany imports of wheat were banned and its production at home was heavily subsidized. By the middle of the 1930's, wheat sold for $1.55 a bushel in France, $1.97 in Czechoslovakia, $2.29 in Germany, and $2.47 in Italy. At the same time the United States and the other efficient world producers and exporters (Canada, Australia and Argentina) were *restricting* production and were unable to average more than about 75¢ a bushel for their wheat.

Economic unity in Europe must ultimately mean a freedom to trade not greatly different from what we have within the United States. Given economic unity and the large markets which go with it, efficient mass production will develop. With Europe receiving cheap supplies of such staple foods as wheat, pork, lard and dried fruits from overseas, European farmers can prosper by specializing in producing fresh foods—butter, cheese, eggs, fruits, vegetables.

Then European agriculture will be more prosperous producing its specialties, and our agriculture (and that of the other great efficient surplus-producing countries as well) will have greatly expanded markets for our staples.

With a cheaper food supply for Europe—yet one yielding a better price for our agriculture—European labor will live better. Labor now used uneconomically for agricultural production will be released for industry. With big machines and semi-automatic processes European labor can produce more steel, automobiles, furnaces, plumbing and electrical appliances to advance its standard of living in coming decades, as the United States has done in past decades.

A rising standard of living in Europe will bring

Europeans to view peace with optimism and hope. And world trade grows as confidence and prosperity widen.

☆ ☆ ☆

How would a Europe which possesses economic unity appear to us on this side of the Atlantic?

It would be a prosperous Europe that would have strength in its advancing industries, but as the single great agricultural deficit area of the world, it would be dependent upon overseas supplies for vital agricultural staples. This dependence upon overseas agricultural supplies would be greatest for industrial Germany. Some people believe that a strong Europe would be a threat to world peace. More important, however, is the fact that a strong and prosperous Europe would not be a frustrated Europe. It would have found a way to achieve a rising standard of living. Furthermore, a prosperous Europe would, economically, be a dependent Europe because, although the European industrial worker would use more and cheaper food, he would have it only as long as he maintained the peace.

A prosperous Europe would be of special advantage to American agriculture (if we do not keep on pricing ourselves out of the market) and of great advantage to American industry.

The British policy of buying agricultural staples from abroad, for example, made her, a nation of only 45,000,000, the purchaser, in 1937, of $250,000,000 of all kinds of agricultural products from the United States. In the same year the rest of Europe (exclusive of Russia), with a population of 325,000,000 purchased only $300,000,000 of our agricultural products. But with more sensible organization of its agriculture, Europe could be expected to buy more than one billion dollars of agricultural products from us.

By far the greatest market for an expanded European industry will be Europe itself.

For American industry, there will be growing markets in Europe as industry expands. Experience shows that the trade between different highly industrialized areas is large. This country's biggest export markets have been with its keenest competitors—Britain, Canada, Japan, France and Germany.

Before the war, Europe, with two and one-half times the population of the United States, had only one-sixth as many automobiles.

If Europe (exclusive of Britain and Russia) were to motorize proportionately, it would need 75,000,000 automobiles. With normal depreciation this would ultimately mean 10,000,000 cars to be produced annually to replace worn out cars.

If one still wonders about the immense number of things Europe might produce *for herself,* let him calculate the highway expenditures, the filling and repair station businesses that must be equipped and maintained; and the doubling of the steel production that would be required to make the automobiles themselves and to reinforce with steel even a moderate amount of additional concrete highways.

Another example is the electrification of Europe. With two and one-half times our population Europe's consumption of electrical energy would be 175 million electrical H.P., if the European worker were to have the advantage of as many H.P. as the American. Yet, just prior to the war, Europe's installed operating capacity was only about 40 per cent of this figure.

☆ ☆ ☆

What has been sketched for Europe is actually much more nearly a page from the economic history of the United States than it is mere prophecy about a desirable future for a Europe at peace. But how can it be achieved? And what is our part to be in helping to bring it about?

Economic unity can be provided for the sovereign states of Western Europe by the peace treaty or treaties adopted at the end of the war. The provisions for securing *economic unity* in Europe should specifically cover:

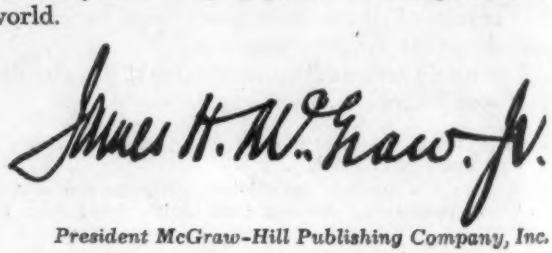
1. Substantial freedom for persons and enterprises to do business anywhere in Europe.
2. Reasonably free movement throughout Europe of persons for employment, recreation and education.
3. Greatly increased freedom of trade:
   a. Within Europe—through the application of a Europe-wide agreement reducing the tariffs among all European countries to a maximum of 10 or 15 per cent.
   b. With the rest of the world—through reduction of European tariffs on goods bought from overseas. This would call for generally lower levels on manufactured goods, and for the removal (after a reasonable period of progressive reduction) of tariffs on all agricultural foodstuffs and most industrial raw materials.
4. A special currency provision requiring as nearly as practicable complete currency stabilization for all countries of Western Europe among each other.
5. Creation of an agency (with adequate revenues) through which all Europe-wide business and other affairs affected by these agreements would be administered for a minimum period of twenty-five years.

This would permit the economic unity of Europe to be substantially achieved. During this period, assistance in administering the provisions would be given by officials of the United Nations.

Near the end of such a period arrangements could be made for a vote in the European countries on whether or not to continue the "unification provisions." If the vote were in the negative, the United Nations would have proper warning that additional safeguards would be necessary to prevent war.

The suggestions made in this statement aim at securing economic unification of Europe and thereby promoting the possibilities of permanent peace in Europe.

The realization of these possibilities throughout the postwar years requires a freely expressed public opinion in Europe to guide all who share the responsibility for bringing peace to Europe and to the world.



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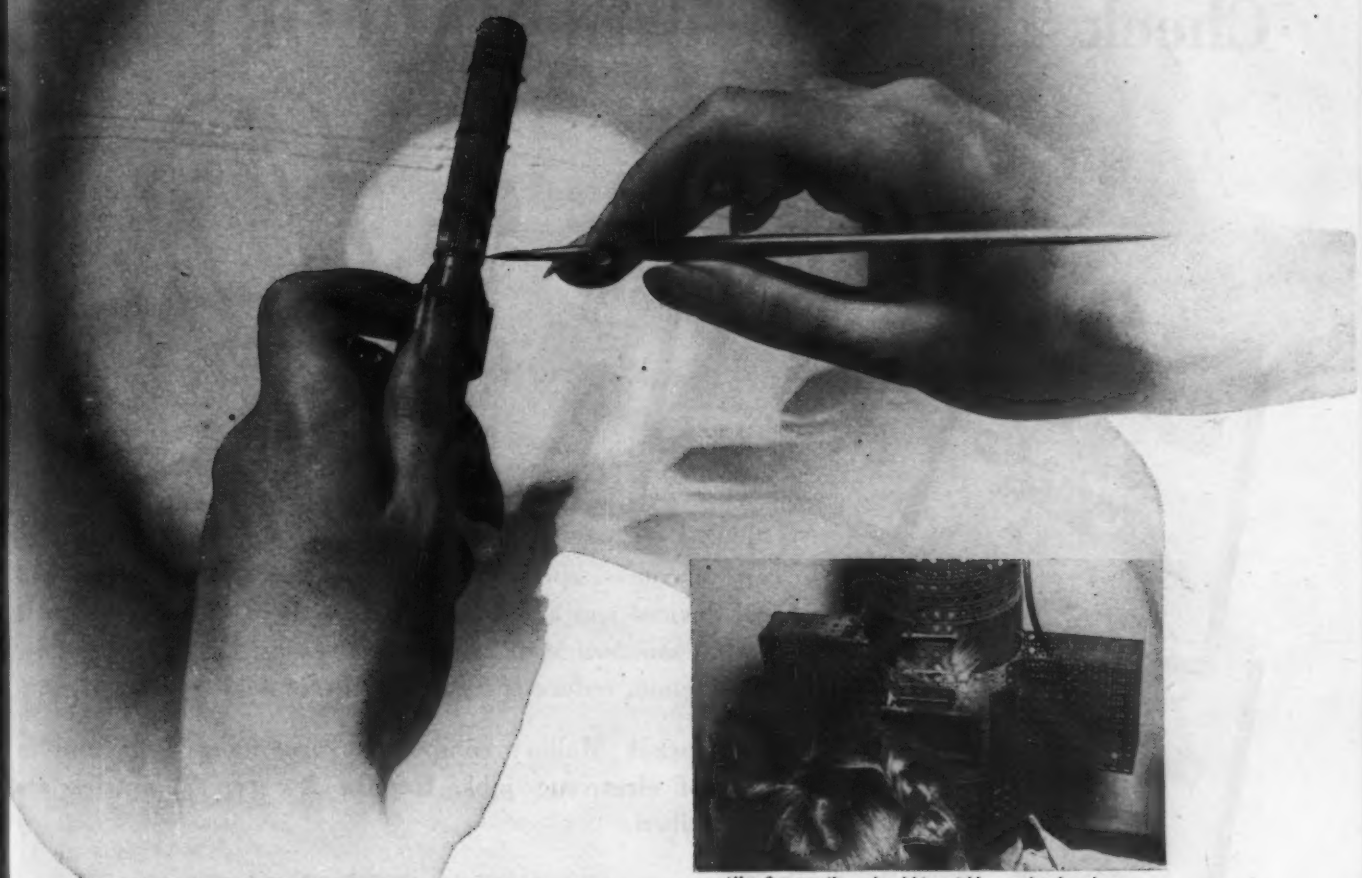
elding with a paint brush?



Alloy flows easily and weld is quickly completed under arc.

solve a difficult welding problem, Eimac laboratory nicians compounded a welding alloy that could be ied with a paint brush. The alloy flows easily under rc to complete the weld, yet subsequent heating to peratures as high as 2900 degrees Centigrade will destroy the weld.

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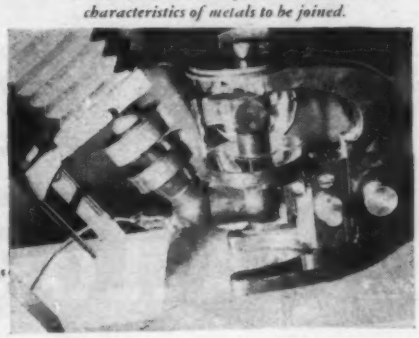

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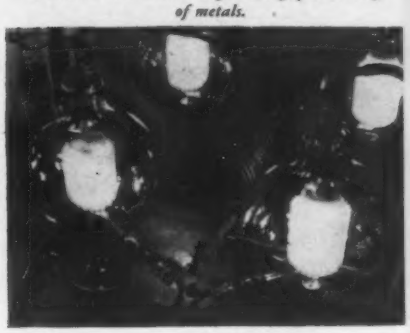

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CROSS TALK

▶**LEGITIMATE . . .** For the first time in many moons, the editor has been sandbagged into going to the theater. It was quite an experience, and not altogether to be recommended to anyone out of practice.

In the first place, in the legitimate theater, in case you have forgot, the orchestra is right down in front, between the audience and the singers or actors. There is only limited volume control, apparently, so that half the time the orchestra drowns out the singers. In the second place, the singers and actors are only natural size, not blown up real big as in a movie, and they are located down in front instead of up in front. Theater seats are so arranged that you can see around nearly everyone except the people in the row right in front of you, and these people always want to look right when you look right and vice versa. The result is, you seldom see much but the edges of the stage. There is also a fairly unsatisfactory acoustical arrangement so that it is difficult to make out the words without a libretto or something.

Some steady radio listeners and movie-goers complain that the drums and violins always seem to come from a certain part of the pit in the regular theater, but we didn't mind this so much—although it did sound strange. Others complain that the bass isn't loud or boomy enough but, on this score, maybe the fellow who plays the bass viol will, in time, make it sound like a radio. People do like bass, you know.

▶**BONANZA . . .** Disappointment stares into the faces of members of the legal profession who look to the end of the war as a time to make their fortunes fighting patent infringement suits based on everybody's use of everybody else's patents. With the aftermath of the last World War in mind, when claims to the tune of some two billion dollars arose, Government has acted early and wisely this time to circumvent difficulties of this nature.

In a few cases exorbitant sums were asked for the privilege of using patents or inventions to aid in the war. These offers were flatly refused and the claimants then had the opportunity of taking the matter to the Court of Claims. As a result, most of these get-rich offers have been scaled down so that the Government got the use of the inventions at a reasonable cost.

It looks, then, as though the infringement suits which took so many years to settle after the last World War will not even arise this time. Lieutenant Colonel Lippincott of the War Department, who has had a lot to do with the happy sharing of inventions and patents for prosecution of the war, says: "Even we patent attorneys will not suffer in the long run" from the amicable arrangements between inventors and Government that have been worked out."

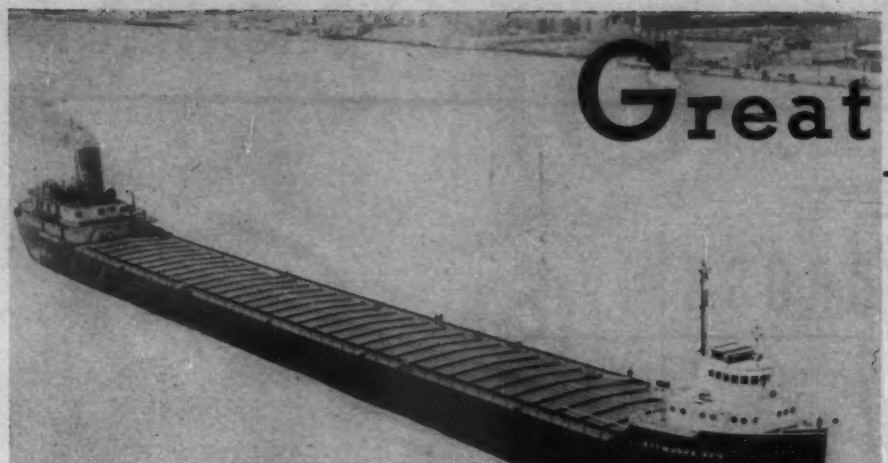
▶**SYMBOLS . . .** To the first engineer who submits an acceptable paper containing circuit diagrams *using the ASA component-part symbols* printed on page 93 of our July issue the editors of ELECTRONICS offer a free lunch, with all the trimmings. We'll buy it here in New York, adding our own personal charms in the event that the lucky man is in this neck of the woods. Or we'll forward sufficient cash to cover a meal in the ritziest restaurant in his home town.

ELECTRONICS is now using the standard symbols in all circuit diagrams. Converting old symbols to the new ones on every single circuit diagram accompanying every manuscript is a tough, time-consuming job, with possibilities of making errors. The editors don't like this kind of work—thus the free-meal offer!

▶**SHORT BUT SWEET . . .** Following the 50 to 60 pages of featured papers appearing in the average issue of ELECTRONICS there is nearly as much material again in back-of-book "Departments," indexed on the Contents page. Items handled in brief style usually get that way for one good reason or another. For example, perhaps censorship prevents the editors from immediately securing sufficient data to justify a feature article, yet they wish to keep readers as fully informed as circumstances permit. In no sense does departmental handling imply lack of importance. There is no room in our columns these days for unimportant material.

Discerning readers tell us that they frequently pick up just the ideas they need from the following departments: *Industrial Control . . .* covering the use of tubes in industry; *Tubes At Work . . .* devoted to immediately useful communication applications; *Electron Art . . .* discussing laboratory work pointing to applications just around the corner; *New Products . . .* describing commercially available gear; *New Books . . . News of the Industry . . . Backtalk.*

Great Lakes



TO FACILITATE the movement in the Great Lakes of nearly 200 million tons of bulk freight a year by some 600 cargo steamers, the Lorain County Radio Corporation has developed over the past decade a highly efficient radiophone service.

Ships can be routed while under way, thereby completely coordinating dock and rail facilities. As a result, an estimated 2000 freight cars are saved each day. In addition, the system provides ships with instantaneous contact with the outside world in case of emergency.

Regular weather reports are broadcast over the system, and ships can call one another for additional information.

Completely Automatic

Ship personnel require a communication system for the operation of which no training beyond that necessary for an FCC restricted radiotelephone operator's permit is needed. Therefore, the Lorain company has developed a completely automatic dial-controlled installation for use in the area shown in Fig. 1.

The dial phone shown in Fig. 2 can be mounted aboard ship wherever it will be most convenient. Usually one hand set is mounted in the pilot house, and one in the captain's cabin. Lifting the hand set from its cradle puts remote transmitting and receiving equipment into operation.

One of six two-way crystal-controlled channels is selected by dialing. A lock-out feature prevents dialing the transmitter onto the air on a frequency already in use, except on general calling and ship-to-ship channels. Once the connection is established, conversation is carried on as in usual telephone installations. Voice-operated relays switch the ship's transmitter on and off the air, eliminating the need for a press-to-talk button. At the shore station a voice-controlled relay switches the land line from receiver to transmitter in accordance with the conversation. A noise discriminator prevents operation of the relay by atmospherics.

The main station at Lorain, shown in Fig. 3, is 30 miles west of Cleveland and communicates with ships on all of the Great Lakes. Two other shore stations, one at Duluth and one at Port Washington, cover local traffic in their respective areas. In addition to the Lorain-operated shore stations there are stations operated by other companies in the United States and Canada which handle traffic. About 95 percent of the ship installations were, however, made by the Lorain Company.

Marine Communication Network

Communication is handled on ship-to-shore frequencies in the 2, 4, 6, and 8 Mc bands; a ship-to-ship channel in the 2 Mc band; and an emergency channel in this latter band. The frequencies used were chosen to give complete coverage on the Great Lakes. Calls are routed over channels which will give the best service at the particular season of year, time of day, and distance to be covered. From the shore stations connection is made to shipping offices, weather bureau and elsewhere over telephone land lines.

Equipment Aboard Ship

The ship equipment comprises a six-frequency crystal-controlled transmitter, six crystal-controlled

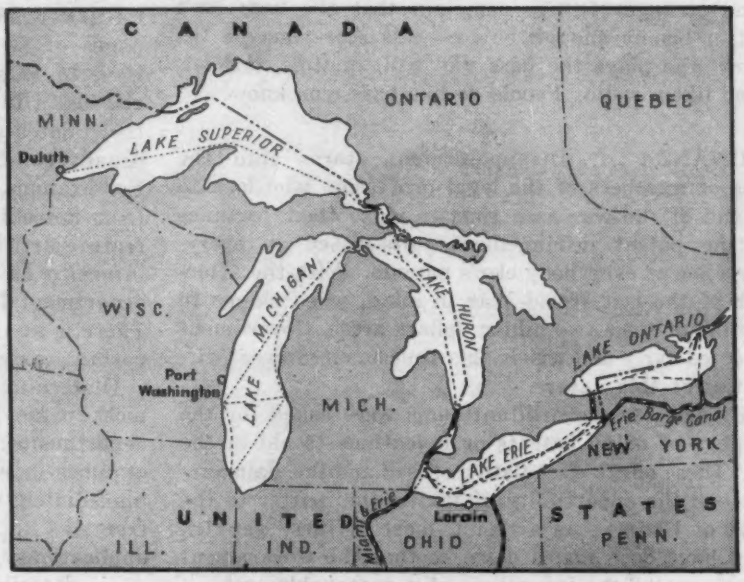


FIG. 1—Location of Lorain County Radio Corporation's shore stations in the Great Lakes marine communication network, showing relation to shipping lanes

Ship Radio System

Detailed description of Lorain County Radio Corporation's automatic service employing dial operation, selective ringing, six crystal-controlled two-way channels, relay-operated transmitters, and voice-controlled terminal equipment with noise discrimination

receivers, power supply and control equipment all in a metal cabinet as in Fig. 4, a transmitting and a receiving antenna, and one or more telephone instruments installed at suitable locations on the ship.

The equipment in the cabinet is assembled on sliding chassis, removable for inspection and servicing. Automatic plug-in arrangements complete all connections when the chassis are slid home. Only the connecting wiring and plugs are attached to the cabinet proper, thus providing complete accessibility of equipment and making it possible to install the cabinet with its rear and side faces against bulkheads or lockers. This feature is of considerable importance on shipboard.

The equipment is completely fused. A main power switch at the top of the cabinet disconnects the power or connects an emergency power supply. The cabinet door is equipped with a tumbler lock to protect the equipment against unauthorized manipulation. In installations where the antenna lead-in wires can not be placed beyond reach, they are insulated in heavy hose.

The transmitter operates directly into a single-wire antenna 50 to 100 feet long, carried as high as possible. The receiving antenna is usually installed on the opposite side of the ship from the transmitting antenna and is connected to the cabinet through a shielded low-capacity rubber-covered lead-in cable.

The equipment operates from 90-115 volts d.c. (the usual electric power aboard ships). The stand-by demand is approximately three amperes; under full operation the installation draws nine amperes. The 500 volts of plate power for the transmitter are supplied by a dynamotor in the base of cabinet. Filters in the ship's power line and in the dynamotor control-unit absorb interference. A rheostat adjusts the dynamotor for operation at the ship's average voltage. The receivers, which are in constant operation, operate directly from the ship's power mains, eliminating the need for a continuously-running converter.

Features of Ship Transmitter

The 50-watt ship transmitter consists of a crystal-controlled 6L6G oscillator and a plate-modulated final amplifier with three RK39's in parallel, shown in Fig. 5 and 6. The three tubes in parallel in the final r-f amplifier permit transmission at somewhat reduced power if one tube fails. Frequency stability is within 0.02 percent.

Individual crystals are provided for operation in the 2, 4, and 6 Mc bands; operation in the 8 Mc band is obtained by doubling from the 4 Mc crystal. Selection of the desired frequency is accomplished under control of the remote telephone dial by means of relays. The relays for the final stage use Isolantite supports for the contact members to

FIG. 2—Wall phone. Cradle holds the hand set securely in heavy weather

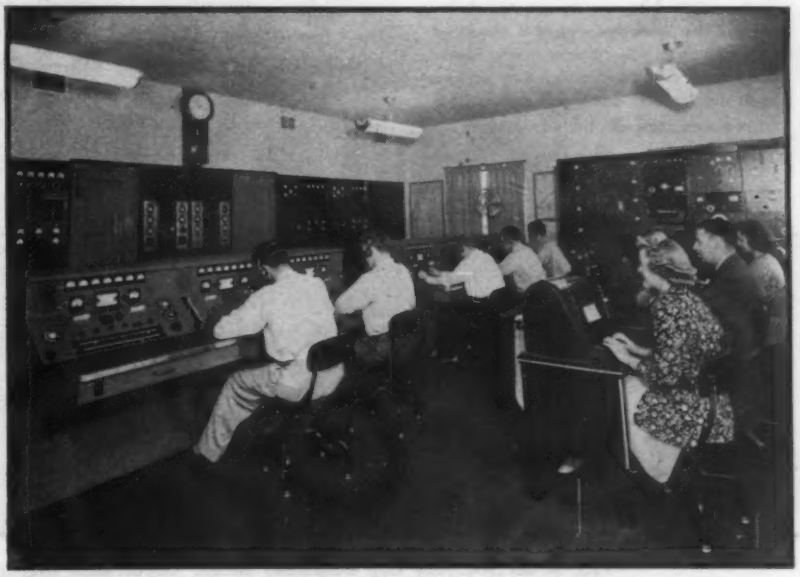


FIG. 3—Main shore station at Lorain on Lake Erie. Each of the six operator positions has push-button selection controlling six transmitters and receivers

FIG. 4—Ship radio equipment, shown with the front door removed. The six-frequency crystal-controlled transmitter is at the top. Immediately below is the modulator and relay assembly. Occupying most of the space in the cabinet are six receivers. The transmitter voltage is supplied by the dynamotor at the bottom. The selective ringer is mounted on the inside of the cabinet door. Meter jacks, fuse clips and adjusting screws are at the front of each unit to facilitate maintenance of the equipment

reduce losses. Complete shielding is provided between the oscillator and final stages. Capacitance-coupling between oscillator and final reduces the number of tuned circuits which must be switched.

The modulator and audio-frequency stages, together with the control equipment, are mounted on a second chassis, shown in Fig. 7 and 8. Carbon microphones in the hand sets and the two stages of speech amplification provide sufficient power for 100 percent modulation of the carrier. All tubes in the transmitter are heated during standby periods so that the transmitter may be started instantly.

Features of Ship Receivers

Six separate complete and self-contained superheterodyne receivers constitute the receiving system. To insure the frequency stability necessary for permanent tuning, the local oscillator of each receiver is crystal controlled.

The use of six complete receivers insures signal reception on all frequencies, obviating the necessity for switching receiver frequencies as the ship passes from the area served by a shore station on one frequency into that of another. This assurance that calls will be received at all times on any of the frequencies employed is of the utmost importance where the distance range of these different frequencies varies with time of day and season of year. Moreover, separate receivers for each frequency make it possible to receive distress calls on the frequency assigned for such calls while at the same time calls can be received on the working frequencies. Calls can also be received on other frequencies if one of the receivers should fail.

Operation of Shipboard Equipment

In making a call the ship operator removes the hand set from the cradle, thereby closing the microphone circuit and also starting the dynamotor. To change the ship's equipment over from the normal standby condition to the calling condition the ship operator dials a two digit number. This number determines which of the six available channels will be used for the call. The channel to be used is chosen on the basis of the type of service desired (ship-to-shore or ship-to-ship), the particular shore station being called, and the prevailing atmospheric conditions.

The dial in the telephone unit transmits a number of pulses corresponding to the digit dialed. These pulses actuate a counting-chain relay system. The first digit is recorded by the counting system, which then locks itself so that further dialing will not change this first count. This prepares the transmitter for operation on the particular channel selected.

In addition to locking itself at the end of the first series of dial pulses, corresponding to the first digit of the channel number, the counting system also switches the common outputs of the receivers from the standby loudspeaker in the hand set units, connects them to the hand set ear-phones, and disconnects the plate voltages from all the receivers except the one associated with the dialed channel.

With the proper channel receiver connected to the ear-phone the operator can tell by listening

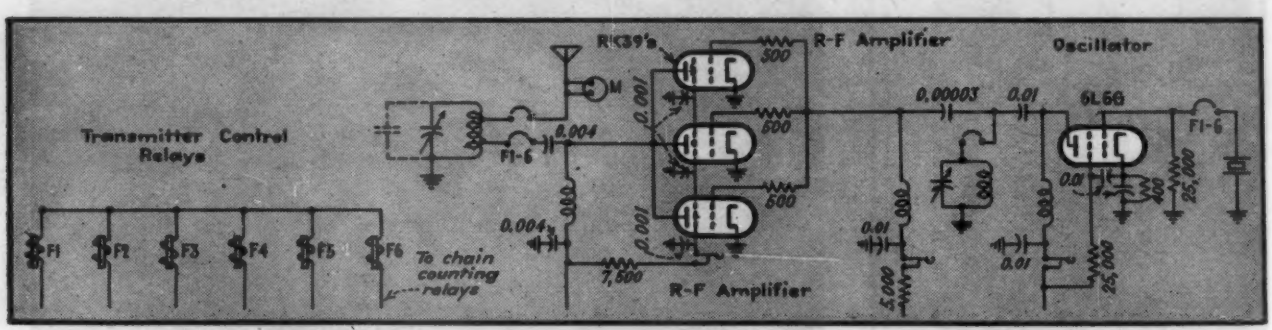


FIG. 5—Six-frequency ship transmitter circuit. Capacitance coupling between oscillator and final reduces the number of tuned circuits which must be switched. The frequency-selector relays are actuated from the chain-counting relays on the modulator chassis

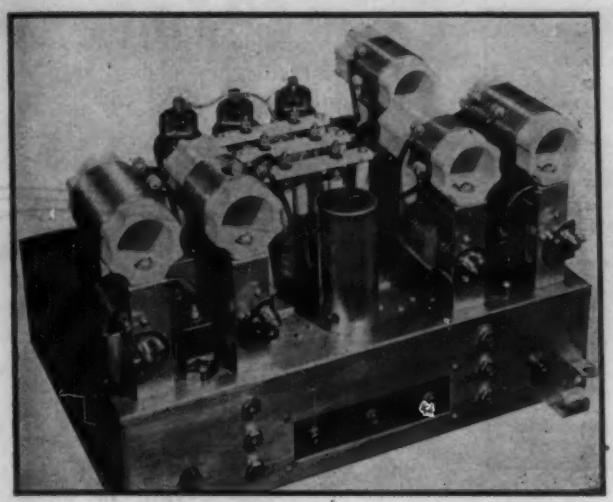


FIG. 6—Ship transmitter chassis with band-changing relays

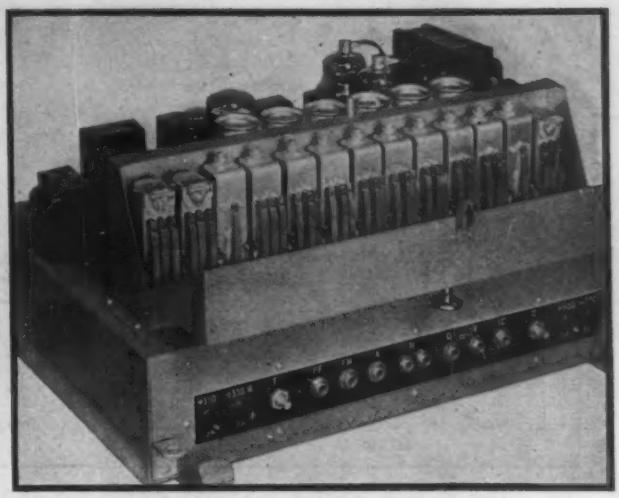


FIG. 7—Modulator and a-f stages, with chain-counting relays

whether or not that channel is in use. If it is, he hangs up and dials another channel; if it is clear he dials the second digit of the channel number. To prevent putting the transmitter into operation on a busy channel, dialing the second digit of the channel number causes avc voltage from the receiver to be applied to a 6C6 "carrier-tube" grid. Should the selected receiver receive a radio carrier, the avc voltage developed thereby and impressed on the carrier tube prevents the flow of plate current through this tube and hence through the transmitter plate voltage relay which is in its plate circuit. The transmitter is thus locked out in the event that the channel dialed is already in use.

If no signal is received, the plate-voltage relay operates, applying plate voltage to the transmitter and closing the circuit to the transmitter channel-selector relay which has already been prepared for operation by the dialing action of the first digit. The transmitter channel-relay acts, placing the crystal and tuned circuits for the selected channel into the transmitter circuit.

The plate voltage relay has another set of contacts which close to apply screen voltage to the 6L6G first audio tube, putting that tube into operation, and also closing a feedback circuit in this stage which converts it from an amplifier to a 300-cps oscillator to generate an attention tone.

The 300-cps tone operates a slow-release voice-relay through copper-oxide rectifiers (used to keep the number of tubes whose heaters must be kept hot to a minimum) which relay closes the oscillator plate circuit of the transmitter, and shunts out 2000 ohms in the grid circuits of the modulator and r-f final stages, thereby reducing the grid bias of these tubes and putting the stages into operation. The transmitter goes on the air modulated at 300 cps.

In operating, the voice relay also inserts 25,000 ohms in the plate supply of the selected receiver to prevent its operation during transmission. Although transmission and reception are on slightly different frequencies in a given channel, the proximity of the ship's transmitting and receiving antennas makes this precaution necessary.

Shortly after the completion of the dialing operation, the feedback circuit in the first audio stage opens. As a result, the slow-release voice-relay takes the transmitter off the air, and returns the receiver to operation.

Speaking into the hand set microphone produces voice signals which, after amplification by the first stage of the audio amplifier, operate the voice relay as did the 300-cps attention tone. The voice relay does not clip words between syllables because of its slow-releas-

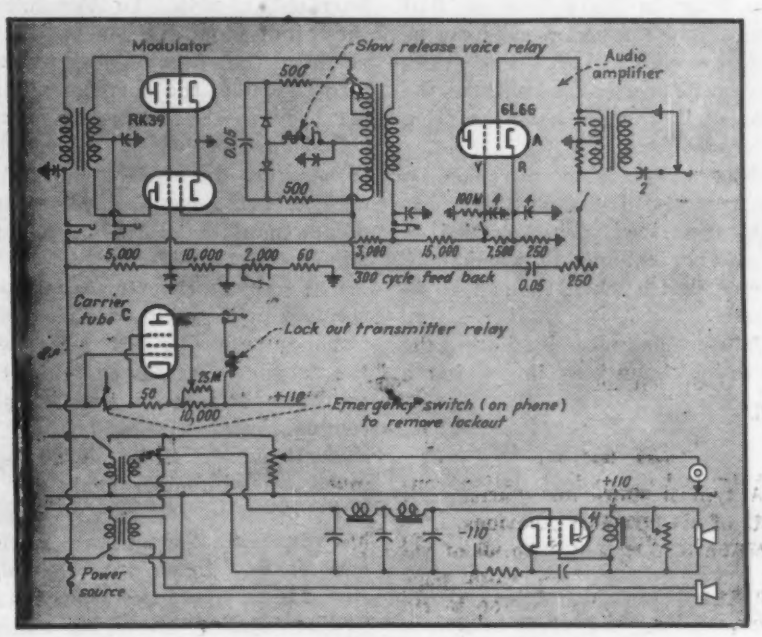


FIG. 8—Ship transmitter modulator circuit and audio amplifier circuits

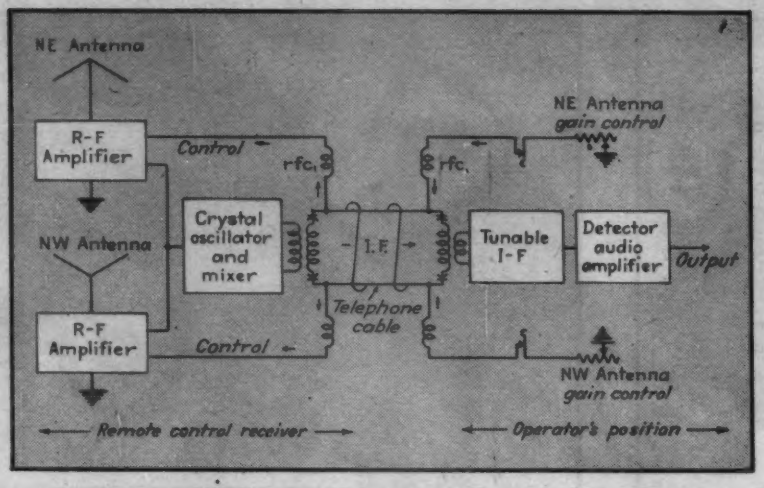


FIG. 9—Block diagram of shore station remote-control receiver.

ing action. When the operator stops speaking, the transmitter is made non-operating, and full voltage is applied to the receiver.

When a call is received aboard ship the signal from the shore station or another ship passes through a low-pass filter whose cut-off is 300 cps, thereby eliminating noise and voice signals from succeeding equipment. In the case of calls from shore stations, selective ringing is employed (as outlined in later paragraphs). The receivers of the channels reserved for shore-to-ship calls have their outputs connected to the selective-ringing equipment through the low pass filter.

The emergency and general-call channel receiver is wired directly to a separate speaker without a low pass filter in its output so that general and emergency calls can be made by voice. In this way emergency calls are received without the delay of lifting the hand set from its cradle.

Calls between ships are made on the general-call channel; the communication itself being carried on on another channel to which both parties switch when the call is received.

Calls are answered by dialing the indicated channel as in making a call.

Shore Installations

A typical shore installation consists of six operator-positions, each position having access to all of the six channels. Each operator position has its own direct line to the nearest long-distance tollboard, from which connection is made to or from the desired land party.

To eliminate interference from the 500-watt shore station transmitters, the shore receivers are located several miles away in unattended remote-control stations.

Each receiver has two directional antennas, one pointing to the northeast, one to the northwest. Each receiver antenna has its own r-f stage. The r-f stages feed to a common mixer with a crystal controlled oscillator. The resulting i-f is fed over telephone cable pairs to i-f stages at the shore station, as shown in Fig. 9.

Because the transmitter frequencies of different ships vary within the permissible tolerances of the channel, the i-f's developed by the crystal-controlled oscillator differ from ship to ship. To take care of these individual differences, the i-f stages at the operator positions are made tunable, the operator tuning precisely to the frequency of the ship being received. This method of handling the signal removes the necessity of remote-control tuning of the unattended r-f stages and mixers.

The gain of the r-f sections associated with each of the directional antennas is controlled over the telephone cable, enabling the operators to choose the antenna combinations which will give the clearest signal. Since all channels must be continuously available for communication the shore stations have duplicate transmitters, one for each channel handled by that station, and an emergency transmitter.

When calling, the shore station should signal only the ship called. To achieve this, a selective ringer has been developed which makes use of tuned-reed relays aboard ship to distinguish one call signal from another.

Selective Ringing

The shore station can modulate its carrier at any one of seven frequencies lying between 120 cps and 300 cps by dialing digits one to seven at the operator position. Four reed-relays tuned to four different frequencies in the available seven-frequency series are used in the selective ringer on board each ship.

To call a specific ship the shore station transmits five tone pulses without intervening pauses. This means that successive pulses must be of different frequencies to be distinguished. Also, since there are but four tuned-relays aboard ship, one of the reed frequencies must be repeated. This arrangement gives slightly over 5000 possible combinations, so that 5000 ships may be called.

The shore operator dials the call number of the ship to be reached. At the ship the audio impulses are delivered by the shore-to-ship receiver, through the low-pass filter which prevents operation of the selective circuit by noise or voice, to a type 41 amplifier tube and thence to the selective ringer. If the first pulse is of the frequency to which the first reed-relay is tuned, the relay operates, connecting the receiver to the next relay in the series. The process is repeated as long as the pulses are of the required frequencies to operate the relays. If at any time the frequency is not that of the next reed, the circuit is opened so that the next pulse can not operate a relay. After all five pulses have been properly received, the selective ringer rings a bell at the hand set location.

Voice-Controlled Terminal Relays

Terminal connection to the shore-party land-line is voice-operated and has an anti-noise feature. Several terminal systems have been tried; the present system, developed from these earlier systems, takes two forms, both of which provide the required operating characteristics.

The chief problem in terminat-

ing the land line arises from the requirement that the land line handle traffic in both directions. This two-way traffic must be divided, the transmission going to the shore transmitter, reception coming from the shore receiver. The transmission loss over the land line is about 15 db, with the result that there is a differential of 30 db between receiver output and transmitter input under the operating conditions which provide the land party with adequate signal strength at the telephone receiver.

If the receiver output, transmitter input and land line were paralleled, the shore transmitter would radiate that half of the conversation received from the ship by the shore receiver, as well as that from the shore party. This means that a receiver tuned to the shore transmitter would receive both halves of the conversation.

In addition to this undesirable lack of privacy, and since the ship transmitter is off the air while the shore party is speaking, the shore receiver—which employs avc—is at its maximum sensitivity when the shore party is talking. Were the direct connection mentioned above used, the noise in the output of the shore receiver would be added to that already present on the land line and fed out over the shore transmitter, with the result that there would be an abnormally high noise-level in the transmission of the shore party.

Both to add to the privacy of the conversation and to reduce the noise in the shore party's transmission, it is desirable to switch the land line to shore receiver or transmitter as the conversation demands. Since the ship transmitter goes off the air when that party has finished talking, it seemed possible to operate a switching relay from either rectified voice in the shore receiver output or the avc voltage developed by the receiver in the presence of a signal, either being an indication that the ship party is speaking. However, noise, especially in the summer on the 2 Mc band in the latitude of the Great Lakes, is so severe as to operate a relay so controlled.

To eliminate the effects of noise, a noise-balancing circuit was developed. As shown in Fig. 10, i-f energy from the receiver is converted by means of an afc oscillator to 55 and 50 kc. Noise in the receiver i-f produces voltages of equal strength at these two frequencies. The two frequencies so produced are rectified and applied in opposition to a d-c amplifier which operates the land-line switching-relay. Regardless of the noise level in the receiver there is no effective voltage applied to the relay amplifier unless a modulated carrier is present. Then the voltage developed in the 55-kc amplifier will increase, unbalancing the system and operating the land-line relay.

As a further precaution to avoid transfer of the land line from the transmitter to the receiver by random carriers crossing the receiver frequency and momentarily interrupting the shore party's transmission, some voice signal from the shore party is amplified and rectified and used to lock the land-line relay to the transmitter position.

The second system in use at present, shown in Fig. 11, is one which (because of its greater simplicity) is displacing the previously described system. It works on the same principle of balancing out two noise-voltages.

In this system one noise-voltage is taken from the superaudible noises present in the receiver; the other is taken from the audible noise voltages. As in the earlier system, these two noise-voltages are balanced, rectified and applied to the d-c amplifier of the land-line switching-relay. When a modulated carrier is present, the audible frequencies predominate, unbalancing the system. If there is no voice-voltage on the land line from which the relay is locked to the transmitter, the presence of a modulated carrier in the receiver switches the line to the shore receiver output.

This automatic ship-radiotelephone system serves the ships of over 30 different companies operating on the Great Lakes. The concentration of shipping in this area, the cooperation of many shipping companies, the spirit of mutual assistance against spring fog and storms on the part of the ship captains, and the absence of international antagonism has made it economically feasible to develop this communication network.

Regular inspection and servicing of the marine equipment, even to the extent of dispatching a serviceman by airplane in case of faulty operation, has assured the reliable operation of the system.—F.R.

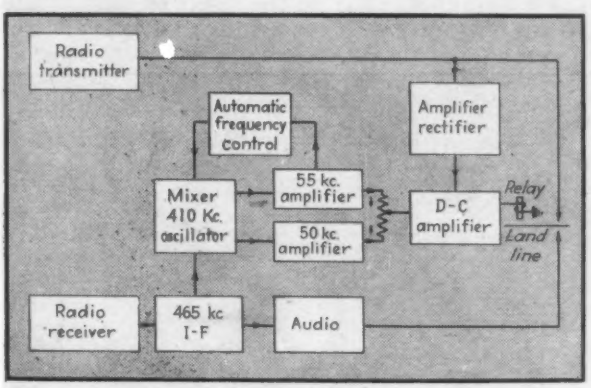


FIG. 10—Frequency-controlled heterodyne oscillator produces two signals, equal in the presence of noise, unequal in the presence of a modulated carrier in this noise-discriminating voice-controlled terminal-relay used in shore stations

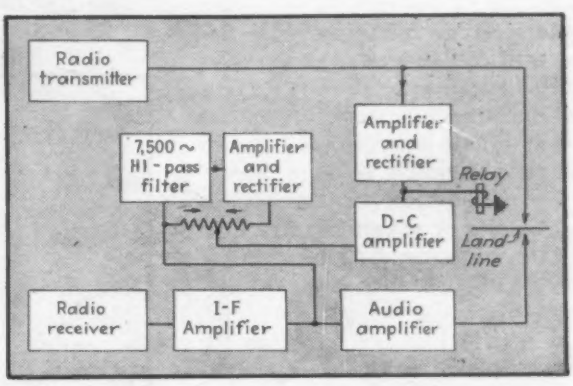


FIG. 11—Noise-discriminating voice-controlled terminal-relay using superaudible noise to balance the audible noise. The presence of voice voltages in the receiver's output unbalances the system

Aircraft Vibration Analyzer

Installed in an airplane for tests during flight, this electronic device provides an instantaneous indication and a graphical record of the amplitude of vibration of the power plant, structural members and controls at certain fixed frequencies related to engine speed

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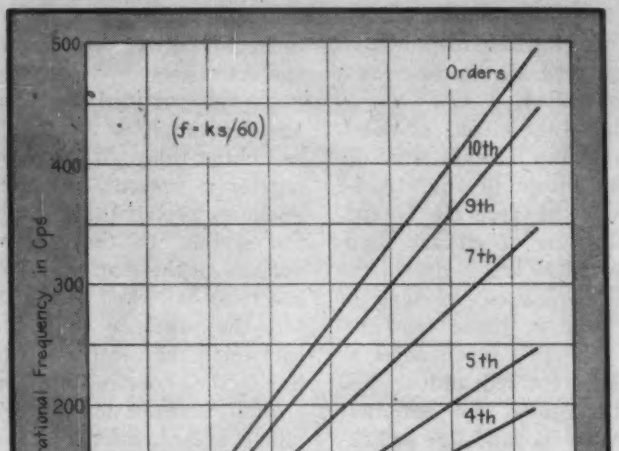

FIG. 1—Curves showing vibration frequency for various "orders" discussed in the text as engine speed varies

ONE important element of aircraft design is the elimination of excessive vibration of the power plant and plane structure during operation. The appearance of excessive vibration at various operating conditions may cause rapid wear or failure of vital elements of the engines or plane structure. In addition, the pilot's flying and combat ability are adversely affected by vibration of the plane's controls, especially on long flights. While theoretical considerations and results of experience are utilized to minimize dangerous vibratory excursions, it is always necessary to analyze the plane's operation in flight in an early model. This necessity results from the incorporation of modifications whose effect cannot be foreseen, such as greater power, higher speeds, lowered weight, new propellers, etc.

Methods of measuring vibrations in planes in flight have been under development for a number of years. Each of these has possessed advantages but all have suffered from the fact that a considerable expenditure of time has been necessary either during flight or while analyzing the data. In addition, some methods have been liable to errors resulting from the fact that data must be recorded and plotted by an observer. To overcome these defects, general requirements were formulated for an automatic system by the Pratt & Whitney Aircraft Division of the United Aircraft Corp. The automatic vibration analyzer was designed to these requirements by the Bell Telephone Laboratories and manufactured by the Western Electric Co. This analyzer in conjunction with an electrical vibration pickup and a recorder produces a curve of the amplitude of vibratory velocity at a given multiple or order of engine speed versus engine rpm.

Nature of Vibrations

Engineers, in their studies of aircraft vibration, have discovered that for the most part power plant exciting forces originate as a result of one or more of the three following conditions: First, they may be the result of inertia unbal-

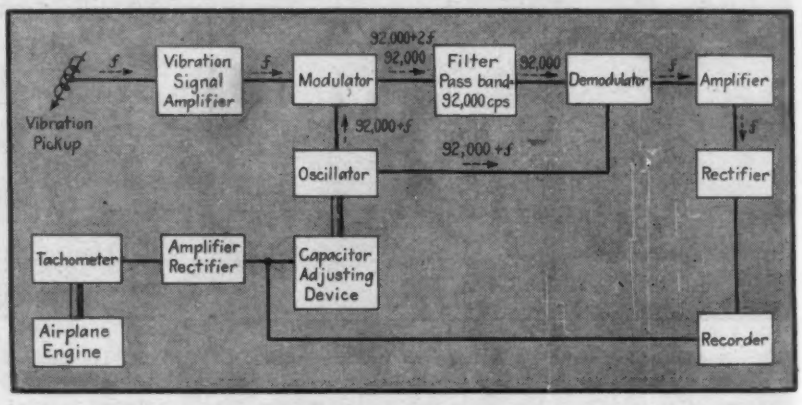

FIG. 2—Block diagram of the analyzer circuit

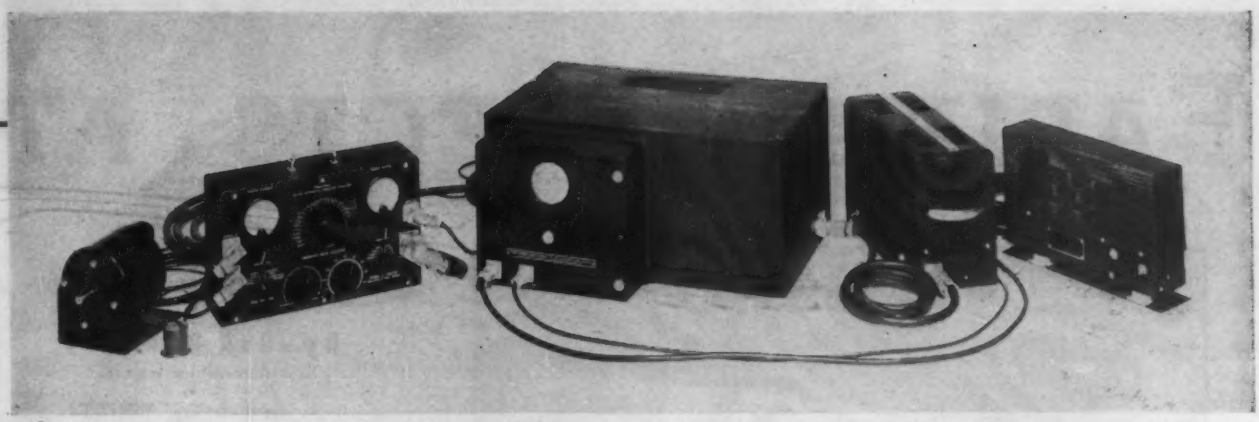

FIG. 3—The test setup, complete except for the recording-pen unit. Left to right: tachometer; control unit for analyzer and recorder; capacitor-drive mechanism and associated amplifier made by the Brown Instrument Co., analyzer power supply and control unit for capacitor drive

FIG. 4—Close-up of the analyzer-recorder control unit

ances in the engine or propeller; second, they may result from forces generated by burning gases in the engine cylinders; and third, they may emanate from aerodynamic forces acting on the propeller. Further, they have found that these vibration-exciting forces occur at frequencies corresponding to definite multiples of engine rpm.

To measure and analyze engine vibrations successfully, it is important to obtain the amplitude of vibration at each of several frequencies for each of a number of engine speeds in the operating range of the standard airplane motor. Consequently, twenty-three frequencies expressed in terms of multiples of engine speed, commonly referred to as "orders," were specified for which analyzer tuning would be required. (In addition, it was requested that provisions be made for five subsequent orders to be specified at a later date.) The final selection of orders was based on possible exciting forces resulting from a number of different engine-propeller combinations. These orders are listed in Table I.

Since the speed range of the standard airplane motor is assumed to be between 500 and 3000 rpm (8.33 and 50 rps), the actual frequencies involved cover a range from the lowest of the twenty-three orders at the lowest engine speed to the highest order at the highest engine speed. Thus the frequencies, being definite multiples of engine rps, will range from 3.33 to 500 cps. Because of the difficulty of separating the low frequencies, however, the full accuracy of the analyzer is not realized below 5.5 cps.

To illustrate the relation between vibrational frequencies and engine speed, several typical curves are provided in Fig. 1. These curves are plots of the relationship $f = ks/60$ where f is the frequency in cps at which the vibration occurs, s is the motor speed in rpm, and k is one of the 23 pre-selected orders.

TABLE I. ORDERS (Multiples of engine speed)

2/5	8/3
1/2	3/1
9/16	7/2
2/3	4/1
1/1	9/2
6/5	5/1
3/2	11/2
8/5	7/1
27/16	8/1
2/1	9/1
9/4	10/1
5/2	

In locating the source of the vibration the key to the source is not the actual frequency at which it occurs but the particular order of vibration, k. Knowing the value of k, the possible sources of the excitation are considerably narrowed down. Although it would be possible to measure the frequency f at which the vibration occurs and determine the engine speed s, then substitute these values in the above equation and solve for k, this is not desirable due to the fact it would require searching for vibration at all frequencies within the band from 3.33 to 500 cps.

Analyzer Circuit Design

The automatic analyzer plots a curve showing the relationship between the amplitude of the vibration and the engine speed for one particular order at a time. The actual frequency of vibration, f, may be readily determined from the previously mentioned frequency equation.

In order to more fully understand

(*Continued on page* 180)

FADING EFFECTS AT

By JOHN B. MOORE
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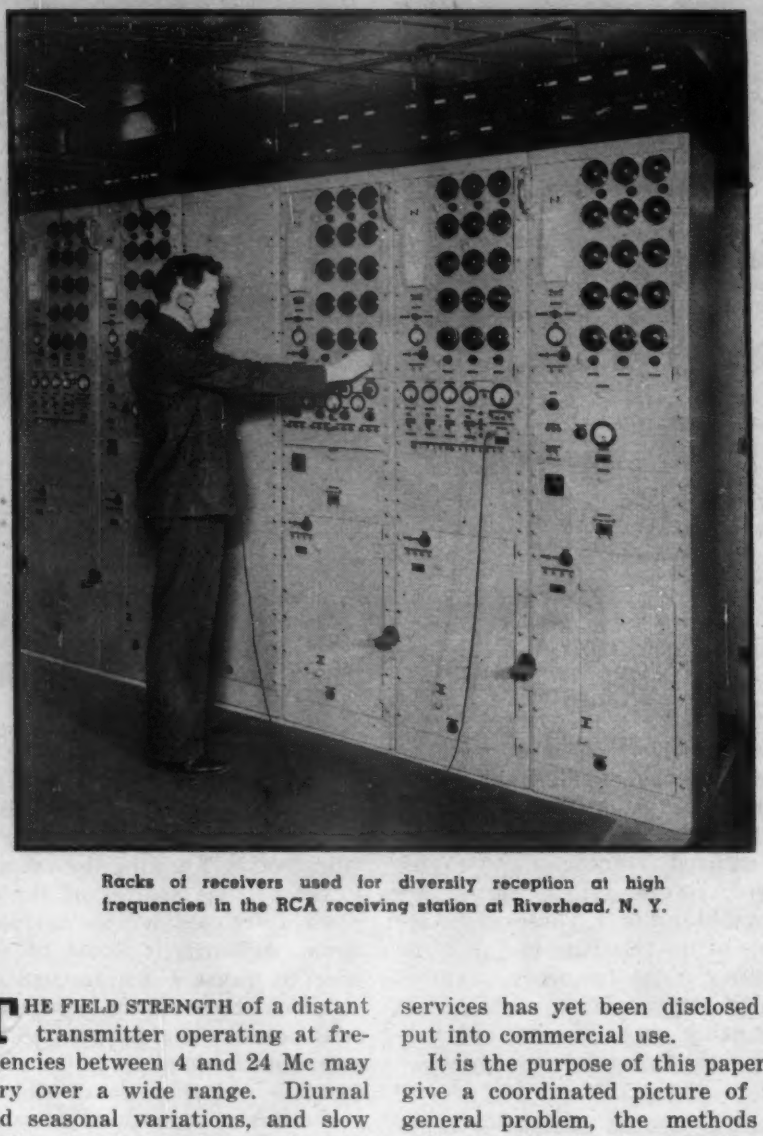

Racks of receivers used for diversity reception at high frequencies in the RCA receiving station at Riverhead, N. Y.

THE FIELD STRENGTH of a distant transmitter operating at frequencies between 4 and 24 Mc may vary over a wide range. Diurnal and seasonal variations, and slow shifts with the sunspot cycle, may be largely if not entirely overcome by the proper choice of carrier frequencies. There remains, however, the problem of insuring satisfactory reception during short-period variations, commonly called fading.

This problem is of particular importance to the commercial communications services, including telegraph, printing telegraph, picture transmission and facsimile, telephone and program services. All are adversely affected in one way or another by fading. No single solution for all types of fading and services has yet been disclosed or put into commercial use.

It is the purpose of this paper to give a coordinated picture of the general problem, the methods of attack employed so far, and the advantages or disadvantages of each method. Violent interruptions or drop-outs lasting from several minutes to several hours or days, caused by terrestrial magnetic disturbances or sun spot activity, will not be dealt with.

Types of Fading

Short-period variations in the signal delivered by the receiving antenna may be of several kinds. The term *fading* will be taken to include any such variation which has a time duration—from normal to subnormal or abnormal and back to normal—of less than one minute roughly speaking, and generally less than one second. The various types will be identified by their outstanding characteristics and effects.

The simplest case is that in which the carrier and all modulation sidebands vary in intensity simultaneously and in the same proportion. This may be a 20 db drop (10 to 1 in field intensity), or considerably greater. Regardless of the depth to which the signal fades, carrier and sidebands retain their original relative strengths. The signal becomes weak, and may even drop below the noise level, but there is no noticeable distortion.

Theoretically at least, this simple type of fading—in amplitude or depth only—may be caused either by: (1) a change in the reflection or refraction of a single ray by the ionized layer then effective in propagating the signal to the receiving point; or (2) out-of-phase addition, and thereby partial cancellation, of two or more rays arriving over paths of slightly different apparent lengths. Such out-of-phase arrival of two or more rays at the receiving antenna gives rise to a number of different effects.

The interference pattern resulting from the out-of-phase arrival of two or more rays sweeps across any given point at which a receiving antenna may be located. At a given instant, and for any specific and discrete frequency, areas or bands of maximum and minimum field intensity just above the surface of the earth (at an-

HIGH FREQUENCIES

Commercial communications services operating between 4 and 24 Mc are adversely affected by field-strength variations of less than one minute duration. The precise nature of the problem depends upon the type of service. Practical methods of minimizing drop-outs, distortion and errors are reviewed.

tenna height) will occur along the direction of propagation as shown in Fig. 1. Generally, the slower the fading the greater the area covered by any one such maximum or minimum.

The interference pattern also sweeps across the frequency spectrum, the frequency separation between maxima and minima varying greatly. Here again, the slower the fading the more widely separated the maxima and minima.

In view of the statements just made, we may say that slow fading generally covers a large geographical area and a wide band of frequencies.

As the fading becomes more rapid, due to the interference patterns — space and frequency — sweeping across the surface of the earth and across the frequency spectrum, the areas of maxima and minima apparently become smaller and the separations between frequencies having simultaneous maximum and minimum field strengths also become less. Under such conditions not only are there rapid variations in field strength of all frequencies within a particular band, but also different discrete frequencies, or very narrow bands of frequencies, do not fade in unison. The result is so-called *selective fading*.

Another effect resulting from simultaneous arrival of two or more rays over paths of appreciably different length is encountered when the time-of-arrival of the rays differs by an amount—measured in milli-seconds—which is appreciable compared to the time of duration of a telegraph dot or of a small element in material being transmitted by radio-photo (facsimile). This is commonly referred to as the *multi-path* effect.

Effects of Fading

The practical effects of the various type of fading shown in Fig. 2 can best be discussed in relation to specific types of radio-communication service. A convenient classification, for this purpose, is:

(1) Slow-speed telegraphy
(2) High-speed telegraphy and multiplex
(3) Radio-photo or facsimile

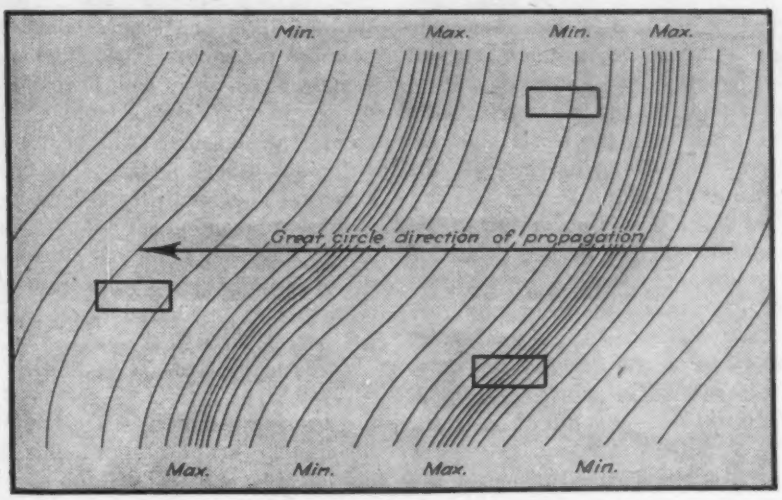

FIG. 1—A typical interference pattern, showing areas or bands of maximum and minimum field intensity. Antennas arranged for space diversity reception are shown as boxes

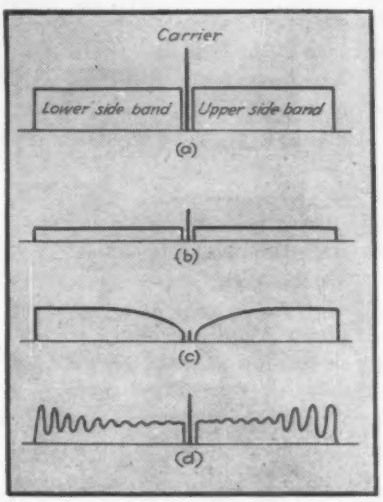

FIG. 2—General types of fading: (a) normal signal; (b) distortionless and non-selective fade; (c) selective fading of a carrier; (d) selective fading of sidebands

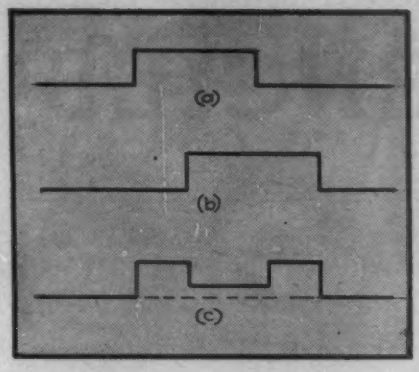

FIG. 3—A "split", showing the effect of multi-path propagation on the formation of a high-speed telegraph dot. (a) The first signal received; (b) the delayed ray signal; (c) the resultant

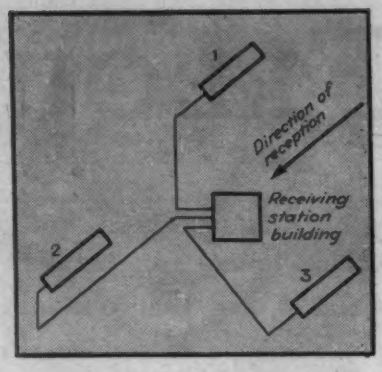

FIG. 4—A space diversity antenna layout. Three directive antennas (shown as rectangles) are placed a number of wavelengths apart, at the corners of an isoceles triangle

(4) Telephone and program services

This classification is based on speeds, or band widths, required.

(1) Slow-speed telegraphy is affected chiefly by the slower type of fading, in which the predominant factor is simultaneous variation of the received field strength of the carrier and all necessary sidebands.

Taking the arbitrary upper limit of 20 dots or square cycles per second for this class of service, and considering that the third harmonic of the fundamental keying frequency is all that is needed for reasonably good envelope formation of the dots and dashes, we see that the total band width involves only 3 x 20, or 60 cps. Observation has shown that such sidebands seldom, if ever, fade differently than the carrier with which they are associated. So-called selective fading therefore is not a serious factor in this type of service.

Multi-path propagation normally does not bother such slow-speed service. The time duration of a dot, at 50 words per minute, is 25 milliseconds. Difference in time of arrival, as between two or more rays, normally runs to a maximum of only about 3 milli-seconds. An exception is the occasional case of long-delayed *echos*, the delay of which is comparable to or greater than the time duration of a telegraph dot or similar signalling element.

(2) High-speed telegraphy includes high-speed Morse or printer operations and multiplex services in which keying speeds may run to 200 dots per second (square cycles per second). At such speed the time duration of a telegraph dot or multiplex keying element amounts to only 2.5 milli-seconds.

It will be apparent, from statements made in preceding paragraphs, that multi-path propagation can seriously interfere with such high-speed telegraphic transmissions. A delayed signal, arriving over a longer path, will result in a dot being elongated, the overall effect being to make the mark/space ratio not 50/50 but perhaps as heavy as 90/10 or even 100/0. Satisfactory reception and transcription then becomes extremely difficult or impossible.

Another effect, due to multi-path propagation, is cancellation of portions of a dot. A common form of malformation, or *split*, is due to out-of-phase addition during the time when both the initial and the delayed rays are being received, the resulting signal dot then consisting of an initial short pulse due to the ray which arrived first, a period of very low or practically zero signal strength during the overlapping of the received rays, and a final short pulse due to the delayed ray only. The resultant is shown in Fig. 3. The duration and depth of the split, in a dot, depends upon the speed of telegraphic transmission, the relative amount of delay between rays arriving, and relative phases and amplitudes of the arriving rays.

Selective fading may affect envelope formation when the fundamental and necessary harmonics of the keying frequency run to 200 x 3 or 600 cps or higher. That is, sidebands removed this far from the carrier may, under conditions of extreme selective fading, fade differently than does the carrier, and an originally rectangular envelope shape will suffer malformation.

(3) Radio-photo and facsimile keying speeds and sideband frequencies generally run considerably higher than for high-speed telegraphic service. Roughly, we may set an upper limit of 3000 cps for systems now in use. Such transmissions obviously will be adversely affected by general fading in depth, by multi-path propagation, and by selective fading. The effects, as observed in the recorded picture, may be streaks, widened or elongated elements of the picture subject matter, and loss of detail.

(4) Telephone and program service sidebands require some 3000 or 5000 cps, respectively. General fading, in depth only, reduces the modulation/noise ratio. Depending upon the action of the receiving system and equipment, this may produce a falling and rising level of modulation output (from the loudspeaker) or a rising and falling noise level.

Selective fading produces distortion having characteristics which depend both on the nature of the selective fading and on the type of receiving system and equipment used. One particularly bothersome type of distortion occurs when the carrier fades but the sidebands remain. The upper and lower sidebands, in the case of double-sideband transmission, then beat only with each other instead of with the carrier. The resulting second-harmonic products are, as is well known, a very annoying form of distortion of the original and intended speech or music.

Reducing the Effects of Fading

The most commonly used method for combatting and minimizing the undesirable effects of fading is automatic gain control (agc), known in some types of equipment as automatic volume control (avc).

This method maintains a reasonably constant reference level for any speech or music modulation. It is effective against the slower, general fading in which the carrier and all sidebands fade essentially in unison and in the same proportion.

If the agc system is designed to act too rapidly, it will follow the lower modulation frequencies and actually, to a considerable degree, remove these modulation components from the final output signal delivered to a loud speaker or other utilization device or circuit. This action is sometimes referred to as demodulation of the carrier. (This use of the term *demodulation* should not be confused with final rectification, or detection, to which the term demodulation often and unfortunately is applied.)

Automatic gain control to take care of general fading of the slower type, is usually used in combination with other methods that are described in following sections. For convenience, these methods are listed here:

Frequency diversity
Space diversity
Polarization diversity
Ray selection and diversity
Limiting
Frequency and phase modulation
Exalted-carrier receivers
Single-side-band.

These general methods will be taken up, separately, in following sections.

Frequency Diversity

This general method derives its name from the diversity, or difference, of fading that often exists on frequencies which may be separated by as little as 500 cps or less. While the basic principle has rather wide possibilities, its practical application has, for various reasons, been pretty much limited to telegraphic services in which the transmission of intelligence is accomplished by keying an r-f carrier on and off. The simplest and probably most widely used system or method has as its purpose the improvement of radio-telegraphic communication without resort to elaborate and expensive receiving systems and equipment. This particular method will be described, by way of illustration.

In the radio transmitter, the carrier frequency is varied or modulated in any manner which will produce sidebands extending roughly 1 kc each side of the carrier. A common method of accomplishing this is to phase-modulate the master oscillator by means of a tone frequency in the neighborhood of 600 cps. The resulting distribution of energy, in sideband frequencies on each side of the carrier, is determined by the degree of modulation. A limited number of sidebands, spaced 600 cps, is a practical compromise between the wide separation desirable for obtaining the maximum benefits of diversity of fading on the one hand, and the disadvantages of interference to signals on adjacent channels on the other. However, distribution of the total available power between the carrier and a large number of discrete sideband frequencies means less power, and therefore less field intensity, on any one frequency.

Rapid fading which would chop or split characters, in the case of a pure c-w carrier, also manifests itself as selective fading which sweeps across the frequency spectrum. At the receiving station, therefore, the adverse effects of such fading are minimized by the employment of frequency diversity —the reception of a number of separate frequencies instead of a pure carrier.

Space Diversity

This system makes use of the diversity of fading existing at geographically separated points, specifically at receiving antennas which are spaced a number of wavelengths from one another. Due to the fact that the system does not depend upon or require any special type of signal, but may be used for reception of all types of high-frequency signals and services, it has been widely adopted.

Three antennas generally are used, as shown in Fig. 4. They may be of any type, directional or not, and are placed at the corners of an isosceles triangle. The exact shape and orientation of this base triangle with respect to the desired direction of reception is not critical.

Generally speaking, spacing between the several antennas should be greater for use at the lower frequencies than at the higher fre-

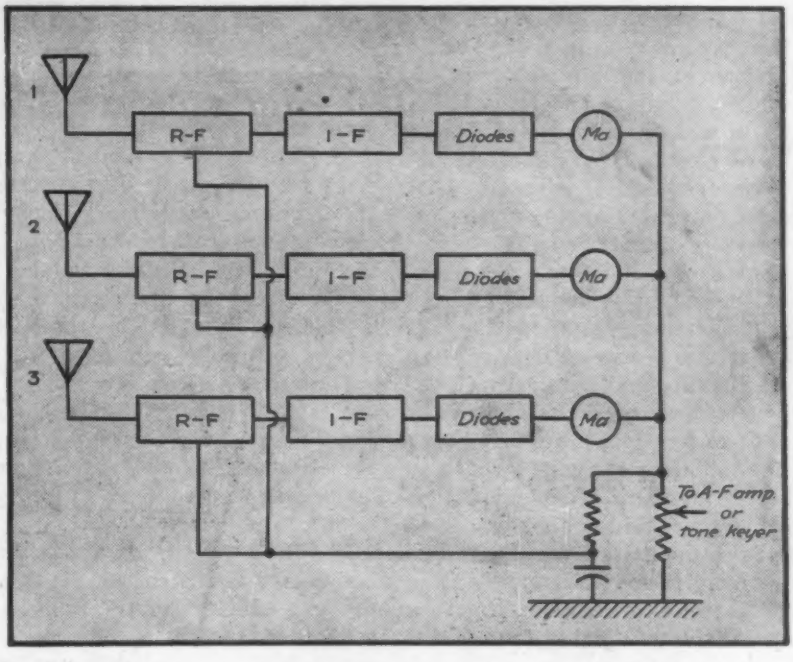

FIG. 5—In this space diversity reception system the rectified output of three receivers is combined, operating the keyer and also supplying bias for automatic gain control

quencies for good diversity performance. A figure of about ten wavelengths or a compromise of about 1000 feet is generally to be recommended, although diversity of fading can be observed between antennas spaced much less than this. However, the greater the spacing, the slower the fading on which diversity action can be expected to be obtained.

In such systems a transmission line of a type having low inherent pickup conducts the r-f signal voltages from each antenna to a separate receiver. The outputs from these three receivers then are either combined or switched, the object being to insure that the utilized output signal will at any and every instant be derived either wholly or chiefly from the antenna at which the best signal-to-noise ratio exists at that instant.

• In telegraph service, and others that similarly employ on-off keying of the carrier, general practice is to combine the rectified outputs from the final detectors of the several receivers. This combined, rectified output controls a keying tube or tubes and also supplies bias voltage for automatic gain control as shown in Fig. 5. The purpose of combining after final rectification is to insure that the outputs from the several receivers will always be additive. If combining in the r-f or i-f portions of the equipment is attempted, addition and cancellation effects will be experienced due to the varying phase relationships between the several signals. This would, in effect, create another interference pattern.

Proper use of this diversity system and action, together with agc to handle slow and area-wide fading, results in a great improvement in reliability and accuracy of telegraphic communication. This is due to the fact that at practically every instant, during the useful period of the day for any given signal, the field strength seldom simultaneously drops to the noise level at all three antennas. Drop-outs, splits and fills are thereby prevented from appearing in the final output signal delivered by the system and equipment.

In telephone and program services, and in others which employ variable depth of amplitude modulation rather than on-off keying, application and use of the space diversity principle is attended by certain complications not met in the case of telegraph service. This is due to the fact that the audio-frequency modulation envelopes of the several signals, delivered by the separate antennas and their receivers, vary in phase. That is, their phases vary with relation to each other as the field-interference pattern sweeps across the antenna locations. Combining two or more such rectified, modulated outputs of approximately equal strengths but out of phase results in a distorted output if the phase differences are very great.

FIG. 6—"Bundles" or groups of rays frequently arrive at the receiving point at different angles. Antenna systems having variable vertical selectivity reduce trouble from this source

The usual arrangement of equipment for space diversity reception of amplitude modulated (phone) signals, applies a common agc to all three receivers. Control voltage is derived from the final rectified and combined output of the three receivers normally employed. The purpose of this common agc voltage is to insure that at each and every moment the receiver getting the strongest signal from its antenna will contribute most to the combined output.

If this were the only selecting action, the contributions made by the individual receivers would be proportional to their input signals received, at the moment, from their respective antennas. Actually, however, there is also a considerable degree of inherent switching action, caused by operation of the final diodes of the several receivers into their common load circuit in which the combining of outputs is accomplished. This action is to completely cut off the output or contribution from the diodes of one or two receivers when the output from another rises appreciably above them. As a result of the common agc, and also of the diode action described, a ratio of antenna voltages of as little as two to one (or less) may result in the entire output signal, in the combining circuit, being supplied by the one receiver momentarily having the strongest antenna signal.

The result of this switching action is that distortion occurs only at those instants when the signal delivered by one antenna is increasing in strength and that delivered by another antenna is decreasing in strength and the two momentarily are about equal in amplitude but differ in phase. This effect is minimized by reducing the value of the differential, between the two signals, required to effectively switch; that is, by cutting off the weaker and permitting the stronger to contribute the entire output current present in the combining circuit. Reduction of the required differential results in more rapid switching, and thereby reduces the time duration of the distortion that is experienced.

Proper use of space diversity action, together with agc, insures the best possible signal-to-noise ratio at every instant, and maintains that ratio at a more nearly constant value than is possible by the use of a single receiver. On very rapid fading, which may also be quite deep, the second and third receivers fill in during those very brief but rapidly occurring instants when the signal from the first antenna is practically zero.

Polarization Diversity

Where space is not available for the erection of antennas separated by some hundreds of feet, use can be made of polarization diversity reception. The fact that the polarization of a received wave does not remain constant, but varies

from horizontal to vertical and to other skew angles, makes it possible to obtain the benefits of diversity of fading by using one horizontal doublet and one vertical doublet (or other type antenna), both antennas being located at the same spot. Two separate receivers are used, in the same manner as for space diversity reception. The improvement to be expected is, however, considerably less.

Ray Selection and Diversity

As has been pointed out, long-distance propagation of high-frequency signals does not take place over but a single path at any given instant. Angle of incidence of two or more rays, or bundles of rays, can be observed and measured, as shown in Fig. 6. By selecting only one of these rays, or small bundles of rays, the effects of ray interference can be greatly reduced.

The so-called *Musa* (multiple-unit steerable antenna) system, developed by the Bell Telephone Laboratories, accomplishes this. The antenna system and its associated equipment are designed to effectively pick out any one ray, or small bundle of rays, by means of extremely sharp vertical directivity which can be adjusted to the desired angle. When it is thus possible to pick out only a single ray, the field-interference pattern previously discussed is no longer such a source of trouble. Large variations in the vertical angle of arrival must, of course, be followed by adjustment of the vertical directivity of the system. Where the signal is arriving simultaneously over two paths that differ sufficiently in their vertical angle of arrival, each can be selected separately and the two combined or switched for obtaining what may be termed ray diversity or path diversity.

A detailed description of the antenna system, and of the receiving equipment, is given in a reference cited at the end of this paper. Briefly, the antenna system consists of some twelve separate antennas of the rhombic type, erected in a straight line pointing in the direction of the desired reception. Rather elaborate provisions are made in the receiving building for properly phasing the signals received from the separate antennas. Adjustment of this phasing is the means employed to produce the sharply directive and adjustable vertical pattern desired.

Limiting

Limiting, by means of non-linear circuit elements such as biased or over-driven vacuum tubes, has relatively little value as a means of reducing the effects of fading except when used in combination with other methods.

In receivers used for telegraph service, employing on-off keying of the carrier, limiting may be used to handle small variations still remaining after the use of agc and diversity reception of any type. Care must be taken, however, not to depend on limiting to such an extent that preceding stages of amplification and frequency conversion are overloaded. If this is not guarded against, various types of spurious interference are apt to be experienced.

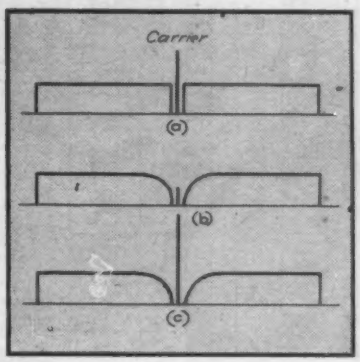

FIG. 7—Principle of exalted carrier receiving system. (a) normal signal; (b) selective fade of carrier; (c) carrier exalted or reinforced at the receiver

In the reception of signals employing variable depth of amplitude modulation, such as telephone signals, limiting obviously can not be used.

In systems employing frequency or phase modulation rather than variable depth of amplitude modulation, limiting is used to eliminate or minimize amplitude variations still existing after the use of agc.

Frequency or Phase Modulation

The use of frequency, or phase modulation as a means of reducing the effects of fading has as its purpose the elimination of amplitude variations in the received r-f signal. Since intelligence is transmitted by varying the frequency or phase, and not the amplitude, it is obvious that limiting can be made use of in the receiving equipment. Some of the variations still existing after the use of agc can thus be eliminated.

Selective fading, due to its random effects on the numerous sidebands that make up a frequency or phase-modulated signal, results in rather serious distortion of modulation such as speech or music. The system therefore does not improve reception which is bothered primarily by selective fading.

It is of interest to note, in dealing with frequency modulation and phase modulation, that certain conditions of propagation partially convert these types of modulation into amplitude variations. One very annoying manifestation of this is the conversion of frequency or phase modulation at power-supply frequencies (hum) into what is effectively amplitude modulation of the received signal. This results in a rising and falling hum level in the a-f output of the receiver. This resultant level of hum may be considerably higher than that measured at the transmitter.

Radio-photo or facsimile services nowadays use some form of frequency modulation almost exclusively. This is applied either to the r-f carrier or to a tone-frequency sub-carrier which then is used to modulate the r-f carrier of a telephone-type transmitter employing any desired system—amplitude, frequency or phase—for modulating its r-f carrier. Advantages of this application lie in the fact that limiting may be applied, in the radio receiving equipment in one case and in the radio-photo terminal equipment in the other case, to eliminate streaks caused by amplitude fading.

The frequency-modulated subcarrier system permits the use of standard phone transmitters and receivers.

Frequency or phase modulation of the r-f carrier itself simplifies the modulation problem in the transmitter, particularly in those

cases in which a given transmitter must be used for either telegraph or telephone services, or their equivalents, on short notice. It also, however, complicates the design of the receiving equipment.

Exalted-Carrier Receivers

Selective fading often reduces the amplitude of the carrier, yet at the same time leaves most of the sidebands at their normal amplitudes. The result is second-harmonic distortion due to the absence of a carrier and the resultant beating of one set of sidebands against the other. The exalted-carrier type of receiver prevents this sort of distortion, by maintaining the carrier at a high level at all times as shown in Fig. 7. Carrier voltage at the final rectifier or detector is maintained at such a high level that the effective percentage of modulation can not exceed 100 percent. Actually, the figure is more like 50 percent or even 30 percent maximum.

In general, two different methods may be employed for obtaining the desired result. In one, the frequency of a local oscillator is automatically held to within plus or minus a few cps, or less, of the frequency of the incoming carrier signal. In the other general method, the incoming signal itself supplies the required carrier which is filtered, amplified, and then re-combined with the sidebands. The same net result may be obtained by the use of a sharply selective i-f system which emphasizes or exalts the carrier and at the same time uniformly reduces the relative amplitude of all sidebands.

The use of a single receiver of this type for reception of amplitude modulated phone signals results in virtually complete elimination of the second-harmonic distortion that otherwise is caused by selective fading of the carrier. To take care of the slower, general fading, it is necessary to supplement the exalted-carrier method with some other system such as space-diversity reception.

Single-side-band System

Complete suppression or elimination of one set of sidebands (upper or lower) and partial suppression of the transmitted carrier, as employed in some phone services, is not intended primarily for reduction of fading effects. Since the system necessarily employs an exalted-carrier receiver, however, it gives the improvement described above.

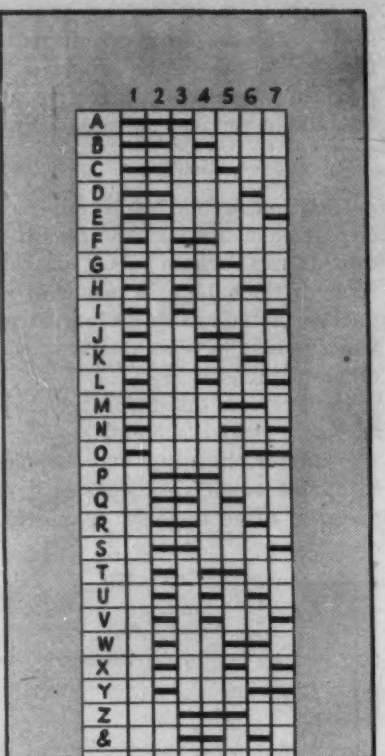

FIG. 8—Seven-unit telegraph code used to prevent printing of wrong letters due signal malformation

Special Code Systems

In view of the apparent impossibility of completely overcoming all types of fading at all times, the problem of providing reliable telegraphic communication has been attacked from another angle. This is to develop a code or system of communication which will tolerate any reasonable malformation of the signal, yet which will not cause an incorrect letter or character to be recorded on the received copy.

This attack has been primarily aimed at development of printing telegraph services. The so-called 5-unit code, for printer service, is so constituted and arranged that the dropping out of one or more impulses (marking bauds) by fading, or the accidental filling-in of spaces by static or interference, will result in the printing of an incorrect letter or character. To prevent such errors, or *transpositions*, there has been developed a code and system which will print a special error indicator sign when the incoming signal has suffered mutilation.

A printing-telegraph code in which each selecting combination consists of only three marking elements, out of a total of seven available per character, provides the required performance. This code is shown in Fig. 8. If either fewer or more than three marking or selecting impulses are received, the receiving machine prints the special error indicator sign. Fading can not, therefore, result in errors or transpositions,—only the special error indicator sign being recorded in such cases.

Summary

It is apparent, from the data given in the preceding sections, that no one method constitutes a complete solution to the problem of fading and its undesirable effects on signals. It also will be apparent that different combinations of the basic methods must be used for different types of service. The particular combination best suited to any given service and circuit depends upon the type and quality of service required and also upon the total cost justified by the business to be handled.

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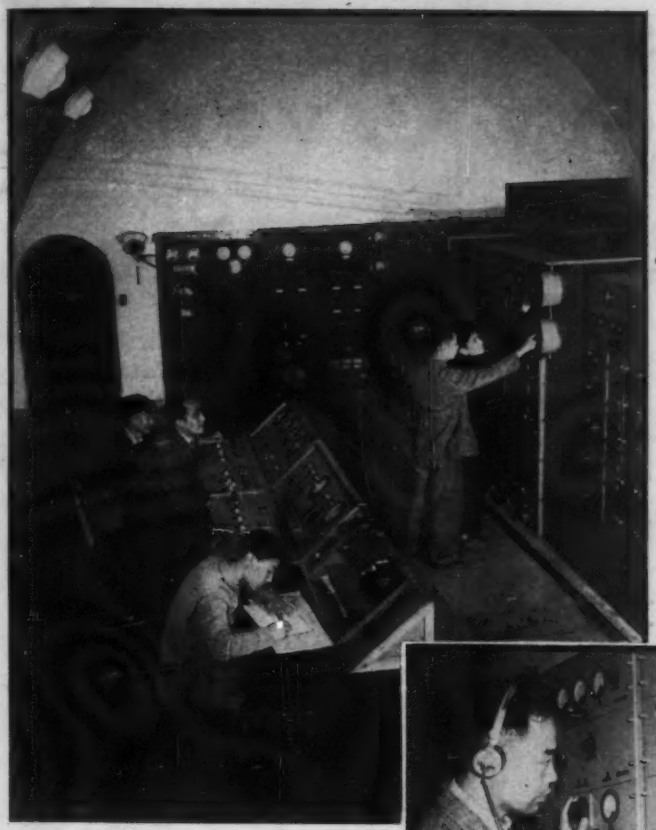
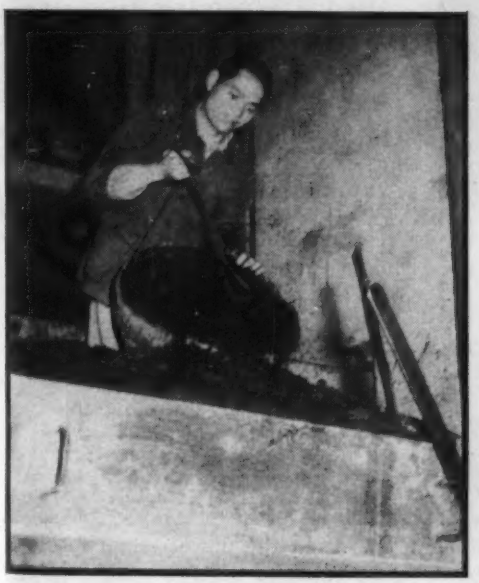
This is XGOY



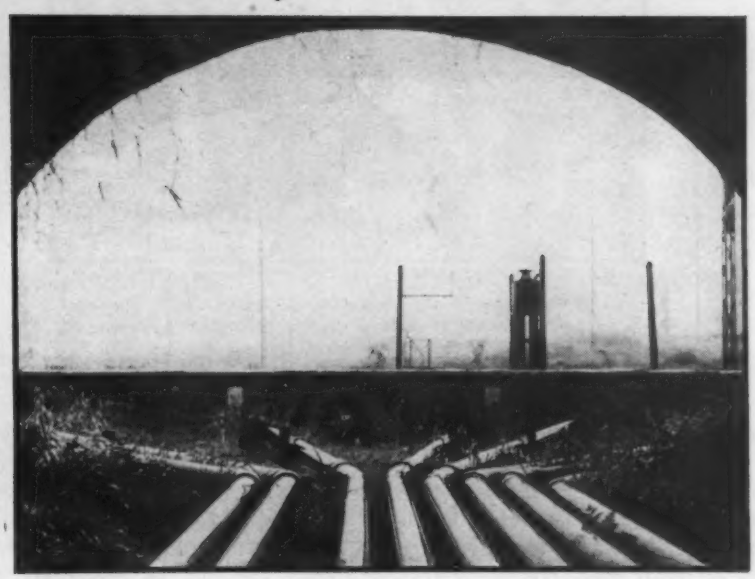
LEFT—Manned by Chinese technicians and located in a deep cavern at Chungking, this Marconi-built transmitting equipment carries the voice of free China to the world. Even direct bomb hits by the Japs have not been able to put it off the air

BELOW, RIGHT—Director of XGOY is Professor Feng Chien, authority on electro-magnetic waves and dean of the college of engineering of the University of Chungking. His training includes time with General Electric Co. at Schenectady and with German AEG

RIGHT — Speech-input tests are made here by Wang Shan-wei, engineer in charge of the transmitter operated by the International Broadcasting Administration. American reception of the station's signal goes to networks through the Ventura, Calif., ham rig of Charles E. Stuart



Power source for the Chungking transmitter is practically spoon-fed to keep within skimpy ration of coal. City power is too undependable for functional apparatus and is used mainly for lights



Beam antennas at XGOY are powered through this series of coaxial cables emerging through cave mouth. American troops in China depend on the station for entertainment and news of home. Other broadcasts are in Burmese, Russian, Dutch, Spanish, Japanese, and Mandarin, each beamed to the appropriate area

Laboratory Oven Temperature Control

Rise and fall of the mercury column in an oven thermometer tunes and detunes a high-frequency oscillator. The resulting variation in oscillator plate current operates relays which turn oven heater current on and off

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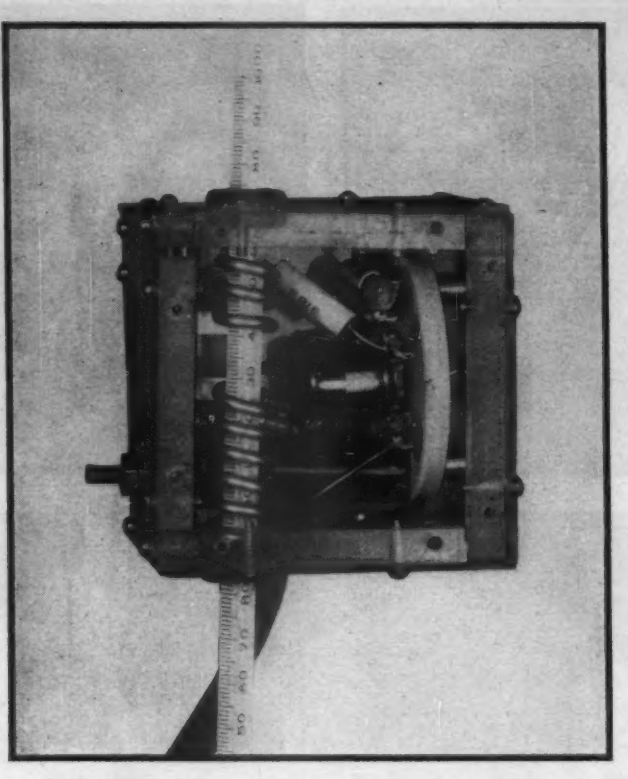

FIG. 2—Close-up of the oscillator unit, shown with the front cover removed. It is light in weight and readily supported by the thermometer which passes through it

THE TEMPERATURE of laboratory ovens may be automatically maintained within ±0.5 deg C by means of the electronic control to be described, the precise accuracy being dependent upon the character of the thermometer used to indicate oven temperature.

The control may also be used as a safety device to cut off heater current in the event that standard controls supplied with stock ovens fail. In this case it is adjusted to operate at a temperature slightly higher than the critical value and takes over control of heater current at that point.

Referring to Fig. 1, it will be seen that the control is built in two separate units, connected together by means of a flexible cable.

Description of Circuit

The oscillator unit, which operates at a non-critical high frequency, is designed around a type 955 "acorn" triode tube and is contained in a plastic case measuring 2½ x 2½ x 2½ in. It is constructed in such a manner that the exposed end of the oven thermometer may pass through the tank coil. Tight rubber grommets hold the unit in place on the thermometer at any position along its length, as shown in Fig. 2. Rise and fall of the column of mercury in the thermometer tunes and detunes the oscillator, altering its plate current.

The other unit contains the power supply and control relays, and is contained within a metal cabinet. The two units may be seen on top of the typical oven pictured in Fig. 3.

Adjustment and Operation

To place the electronic control in operation the power supply unit is connected to the 110-v a-c line and the oven input control leads inserted in the plug on the side of this unit. The oscillator unit is then slid

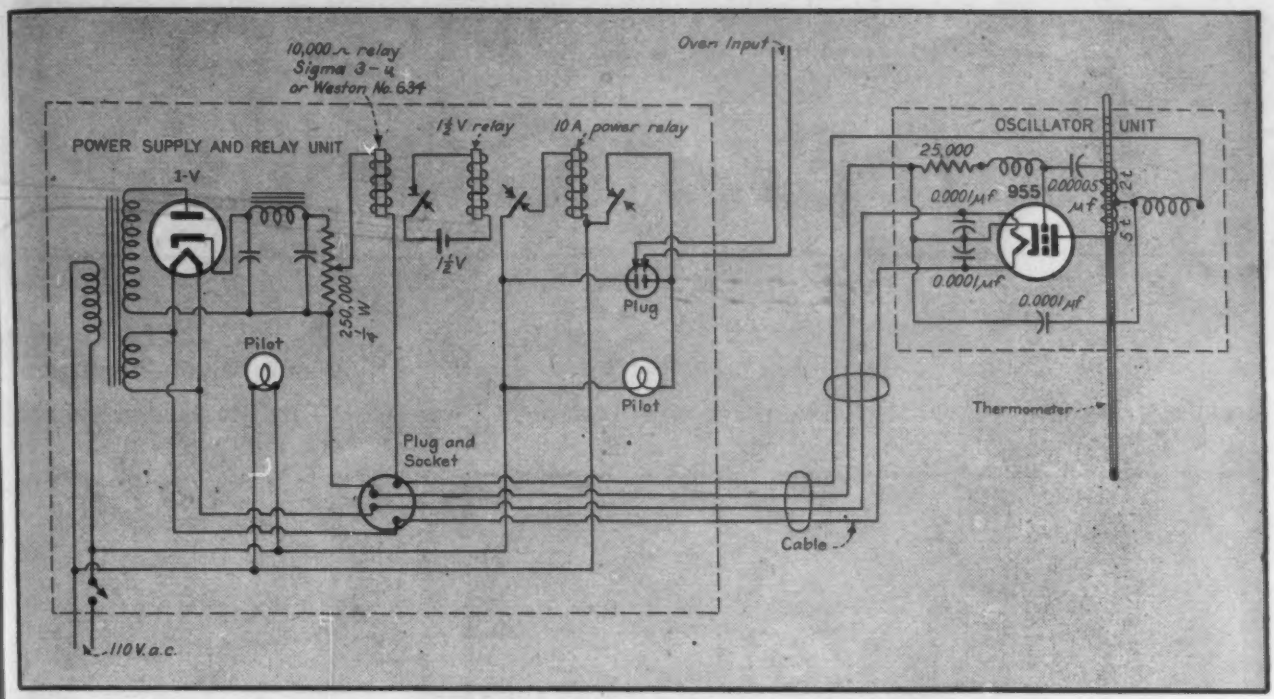

FIG. 1—Circuit diagram of the electronic control device. It is readily constructed from parts available in most laboratories and is relatively simple to adjust

over the oven thermometer and oriented so that the mercury column is level with the plate end of the tank coil at the desired oven operating temperature. Oscillator plate voltage is then adjusted by means of the 250,000-ohm potentiometer so that the 10,000-ohm plate circuit relay just barely closes. Voltage is reduced and the relay opens.

Increase in oven temperature above the desired value causes the mercury column in the thermometer to rise. Inasmuch as the mercury column rises inside the oscillator tank coil the oscillator is detuned, its plate current rises and the plate circuit relay closes. Closing of the plate circuit relay energizes the 1½-v battery-operated relay, opening its contacts. The 10-ampere power relay is de-energized and oven current is cut off. Oven current remains cut off until the mercury column falls to the critical value, at which time inverse relay operation takes place and heater current is restored.

Satisfactory action of the electronic control is largely dependent upon the adjustment of the 10,000-ohm relay. The limiting factors with respect to speed as well as accuracy are, however, the characteristics of the thermometer.

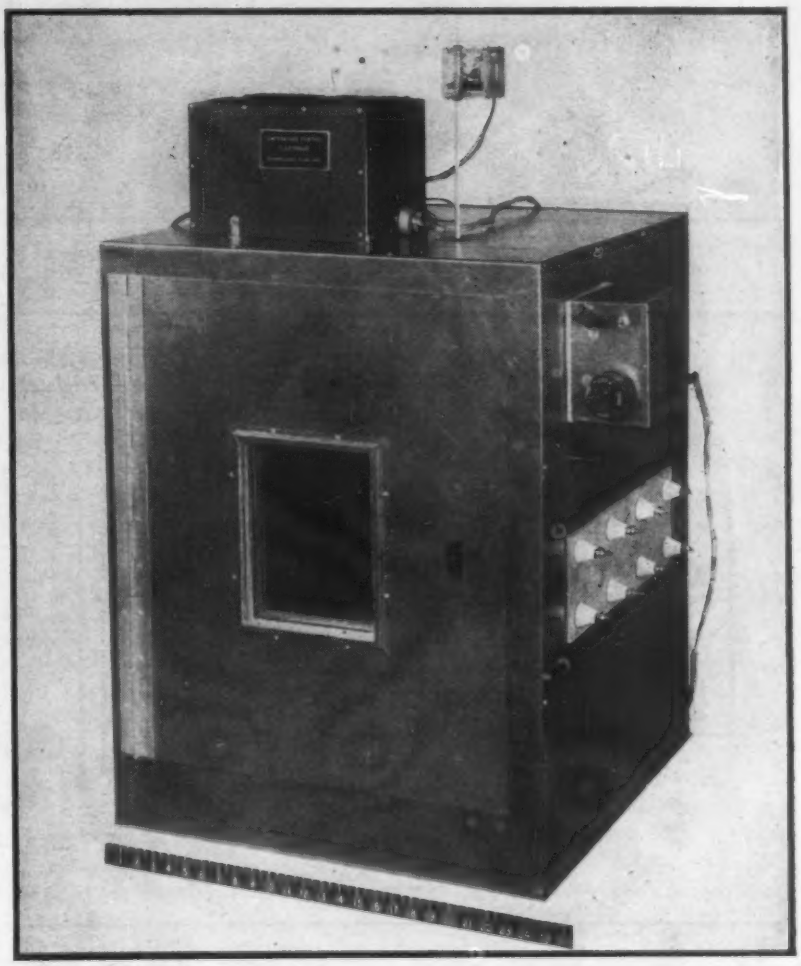

FIG. 3—A typical laboratory oven, showing the two-unit electronic control in position on the top, operating in this instance as a safety control supplementing standard controls

ELECTRONIC
Autopilot Circuits

Detailed analysis of the electronic circuits that function in conjunction with gyros and electric servo motors in the B-29 Superfortress and other Allied bombers to maintain precise straight-and-level flight during bombing runs or finger-tip control of maneuvers

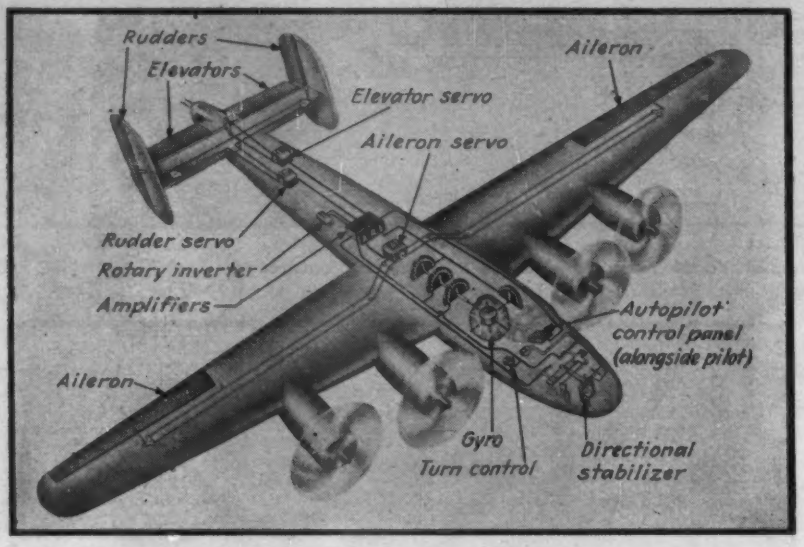

FIG. 1—Drawing showing interrelation but not position of the main component units in the Minneapolis-Honeywell C-1 automatic pilot

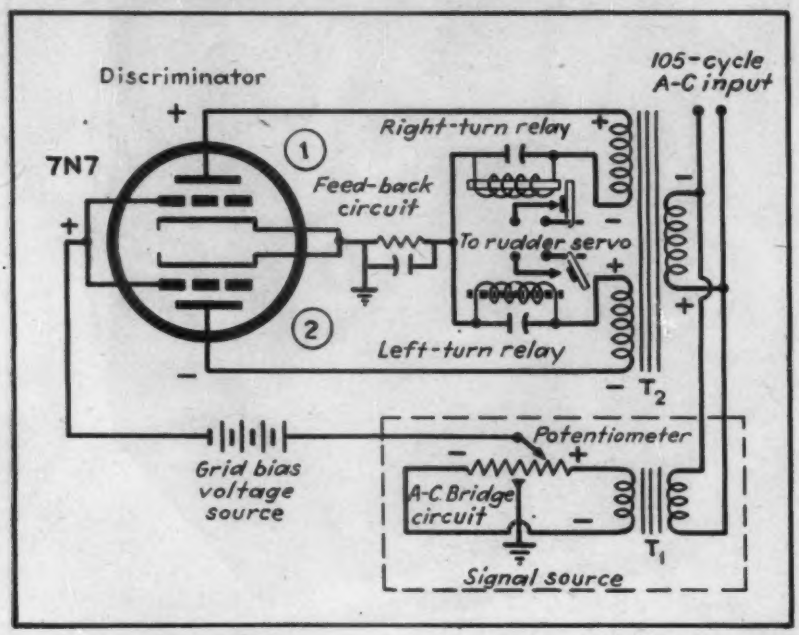

FIG. 2—Simplified schematic diagram of the discriminator circuit used in a single channel of the autopilot amplifier. Two signals, differing in phase by 180 degrees, may enter this stage from the a-c bridge circuit: one makes the right-turn relay operate, and the other makes the left-turn relay operate

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DURING the few seconds of a high-altitude precision bombing run, an airplane must not deviate appreciably in any direction from its set course. To provide a stable platform for such operations, the Minneapolis-Honeywell C-1 electronic automatic pilot is standard equipment on many AAF bombers, including Fortresses, Liberators and the new Boeing B-29 Superfortress.

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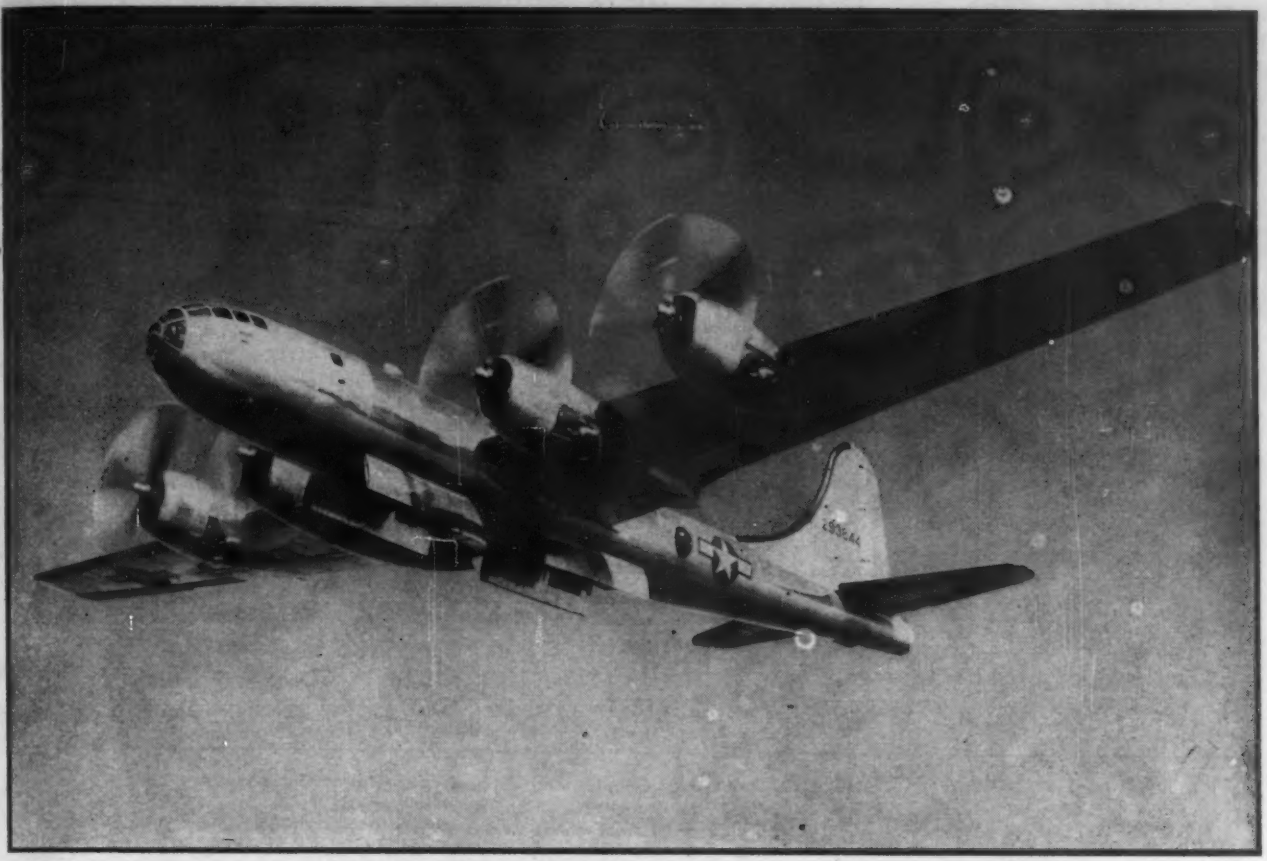
The autopilot works in much the same way as a human pilot. Gyroscopes act as the eyes and the electronic amplifier as the brain of the autopilot in detecting flight deviations. Potentiometers in the gyro housings respond to these deviations and transmit appropriate signals to amplifiers that control the operation of servo units, which are special electric motors that act di-



The C-1 electronic autopilot is used on the Boeing B-29 Superfortress

rectly on the control cables of the airplane.

The precision of even the most skillful human pilot is limited by such factors as his reaction time, susceptibility to fatigue, inability to detect slight variations the instant they occur, errors in judgment and errors in muscle coordination. The autopilot, on the other hand, detects flight deviations the instant they occur and makes the required correction of the airplane's controls quickly. When properly adjusted, the autopilot will smoothly return plane to straight-and-level flight after an off-course deviation, without over-control or under-control.

Acts on Rudder, Ailerons, and Elevator

An airplane is maneuvered by displacing three controls: (1) The rudder, for turns; (2) The ailerons, for selecting rolls and banks during turns; (3) The elevator, for making the plane ascend or descend. Thus for automatic flight three separate control channels are required, each consisting of a servo motor acting on one set of control cables, a gyro-controlled amplifier channel to make the servo rotate in the correct direction for the correct length of time, and the adjusting potentiometers in the autopilot control panel. These features of an autopilot installation are shown in simplified form in Fig. 1.

A pitch-axis deviation (such as sudden dropping of the nose of the plane) calls for corrective action by one control channel only, that serving the elevators. All other deviations necessitate corrective action by all three channels. Thus, if the right wing drops, correction is made by moving the right aileron downward and the left aileron upward. However, since the air under a wing is at higher pressure than air above a wing, the right aileron causes more drag than the left, and the plane tends to deviate to the right. Therefore, both the rudder and the elevator must be moved with the ailerons to correct the original deviation and to prevent loss of altitude.

In the autopilot, ingenious use of potentiometers in balanced a-c bridge circuits provides the required inter-relation of control actions in an automatic manner.

The electronic features of the three channels of a C-1 autopilot are essentially identical, and hence only the circuit of one channel need be analyzed in detail. By considering the turn-control channel in simplified form as shown in Fig. 2, with amplifier and control stages omitted and with the multitudinous potentiometers lumped as a single potentiometer in an a-c bridge circuit, the action of the entire autopilot can be more readily understood.

Analysis of Autopilot Circuit

When the a-c bridge is balanced, no a-c signal is applied to the two grids of the 7N7 discriminator tube and no plate current flows since the d-c bias is fixed at cutoff by a d-c bias source.

The two plates of the discriminator tube are connected to separate secondary windings of the power transformer in such a way that at the instant when one plate is positive with respect to the cathodes, the other plate is negative. The other ends of these secondary windings are connected through the two

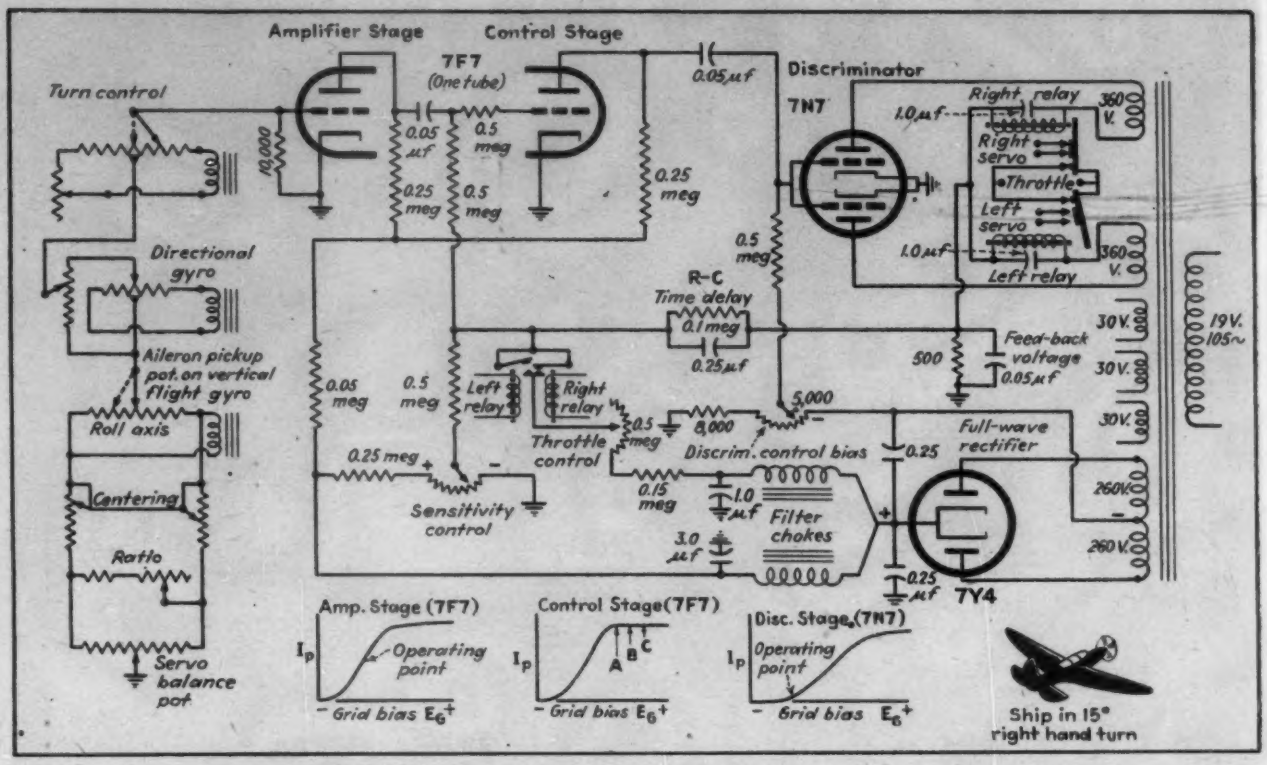


FIG. 3—Complete schematic circuit for the aileron control channel, with characteristic curves showing operating points of the tubes. The complete a-c bridge network for this channel, at the left, provides the required interlocking with other channels for properly co-ordinated turns

relay coils and a feedback circuit to the grounded cathodes of the tube. The bridge circuit is energized by another power transformer, in such a way that when plate No. 1 is positive, the right end of the potentiometer (pot) is positive as shown in Fig. 2, and when plate No. 2 is positive the left end of the pot is positive.

With the tube biased to cutoff, the positive half of any a-c signal applied to the grids will cause plate current to flow through the tube section having a positive plate at that instant. On the succeeding negative half of the signal, the plate current of the tube drops to zero because a swing beyond cutoff cannot cause variations in plate current.

Assume that a deviation of the airplane or operation of the turn-control knob by the pilot causes an unbalance in the bridge circuit, represented by movement of the wiper on the pot toward the right in Fig. 2 as shown. The signal produced by this bridge unbalance is fed through the amplifier and control stage (not shown in Fig. 2) to the grids of the discriminator tube. At the instant when the right end of the pot is positive, polarities in the circuit will be as indicated on the diagram. The grids are both positive with respect to the cathodes, but only plate No. 1 is positive. Therefore, electrons are attracted by plate No. 1 and current flows through the right relay coil, simultaneously charging the capacitor connected across the relay. Operation of the right relay closes the circuit through one operating solenoid in the corresponding servo unit, producing the required correcting movement of the rudder. Plate No. 2 is negative and hence passes no current at this time.

One-half cycle later, the right end of the pot and both grids are negative, hence no plate current flows even though plate No. 2 is positive. The righ-turn relay remains closed, however, because the capacitor connected across the relay coil discharges its stored-up energy through the coil. Thus, the right-turn relay is kept closed all the time the pot wiper is toward the right and calling for a right turn.

When airplane deviation causes the wiper on the pot to move to the left of center, exactly opposite conditions prevail. Plate No. 2 is positive at the instant when both grids are positive, hence current flows through the left-turn relay coil and charges its holding capacitor. This actuates the other solenoid in the servo unit, causing opposite movement of the rudder.

The bridge circuit in Fig. 2 is represented by a single pot for simplicity of explanation, with the center-tap serving as the balance point. Actually, the balance point of the bridge circuit is not fixed, but will shift from side to side depending upon the relative positions of all the wipers in the bridge circuit of the channel.

Complete Circuit for Aileron Channel

The complete circuit for one channel is given in Fig. 3, including the various potentiometers that make up the three a-c bridge circuits feeding this particular channel. The a-c voltage produced by bridge unbalance is amplified by the first section of a 7F7 double-triode, then fed to the control stage where the signals are sorted according to strength. Very small signals are rejected, weak signals are strengthened, medium signals are passed intermittently, and strong signals are

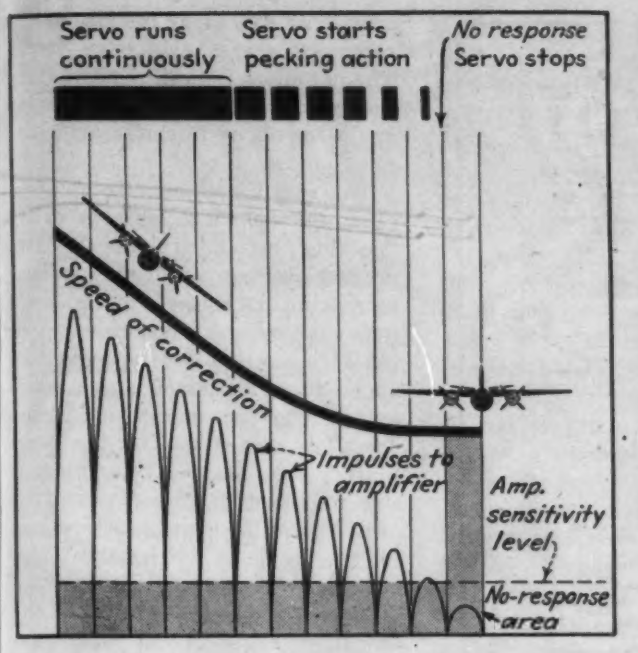
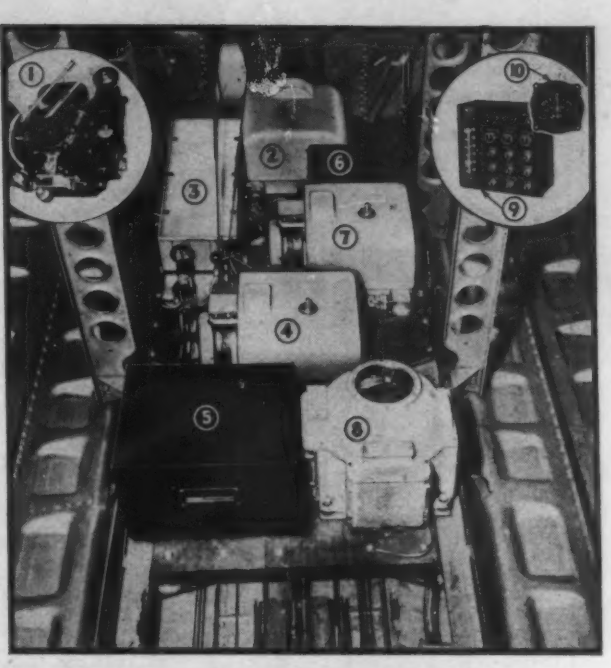
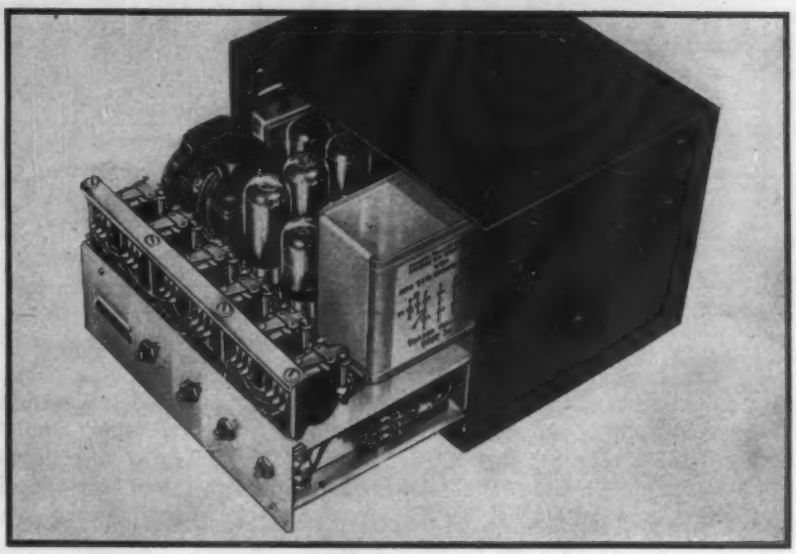


FIG. 4—Curve showing how speed-of-correction decreases as plane returns to straight-and-level flight after an extreme deviation



ABOVE RIGHT: C-1 autopilot as normally installed in an AT-11 airplane, with insets showing the three remotely located units. In other types of aircraft the units are not generally arranged as compactly as here. Identified parts are: 1—directional stabilizer in nose of airplane; 2—rudder servo unit; 3—junction box; 4—aileron servo unit; 5—amplifier unit; 6—rotary inverter; 7—elevator servo unit; 8 vertical flight gyro; 9—autopilot control panel; 10—pilot direction indicator on instrument panel



RIGHT: Amplifier unit of autopilot, with cover removed and chassis pulled out to show the relays and some of the seven tubes making up the three amplifier channels

passed continuously to the discriminator tube.

To accomplish this sorting action, three separate control voltages are applied to the grid of the control tube in the form of a composite d-c bias acting in series with the a-c signal coming from the amplifier stage. By inserting a 0.5-megohm resistor in the grid lead of the tube, a characteristic curve like that at the bottom center in Fig. 3 is obtained for the control tube. When the combined grid voltage is negative this resistor has no effect; when the grid swings positive, however, the resulting grid-current flow through the resistor develops across it a voltage drop that leaves only a fraction of the applied positive voltage actually on the grid. Positive voltage swings thereby have no appreciable effect on plate current, and the characteristic curve levels off sharply at point A on the curve. The three control voltages, called sensitivity voltage, feedback voltage and throttling voltage, serve to shift the operating point of the control tube along section A-B-C of the curve.

Effects of Control Voltages

The first control voltage, which eliminates small signals, is called *sensitivity voltage* because it controls the sensitivity or "alertness" of the autopilot control system. This voltage is obtained from a variable voltage-divider connected in the power-pack circuit of the amplifier, with the control knob being located on the autopilot control panel alongside the pilot. Operation of this control regulates the grid voltage between *A* and *C* (Fig. 3). At *A*, sensitivity is high because the negative peaks of even very small signals will cause the plate current to fluctuate and transmit a signal to the discriminator tube. Normal setting is at *B*, except when extreme accuracy of flight control is required during bombing runs.

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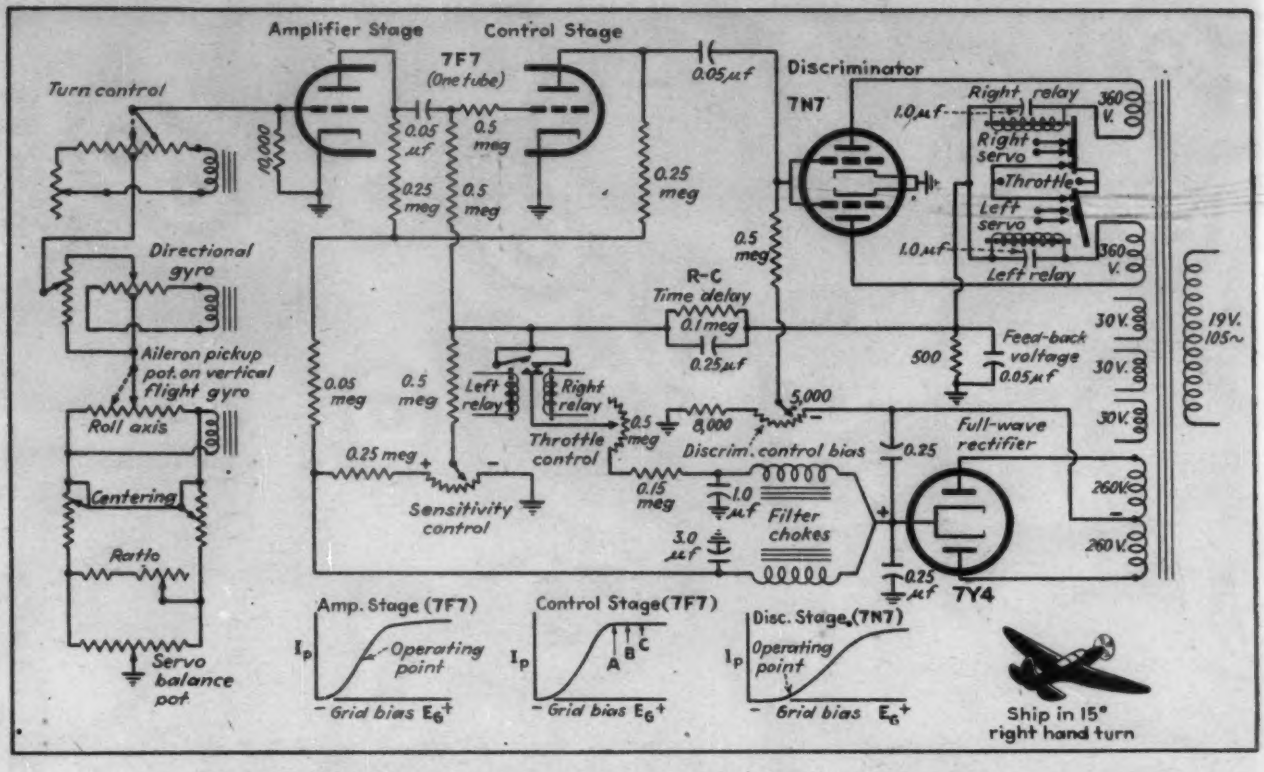

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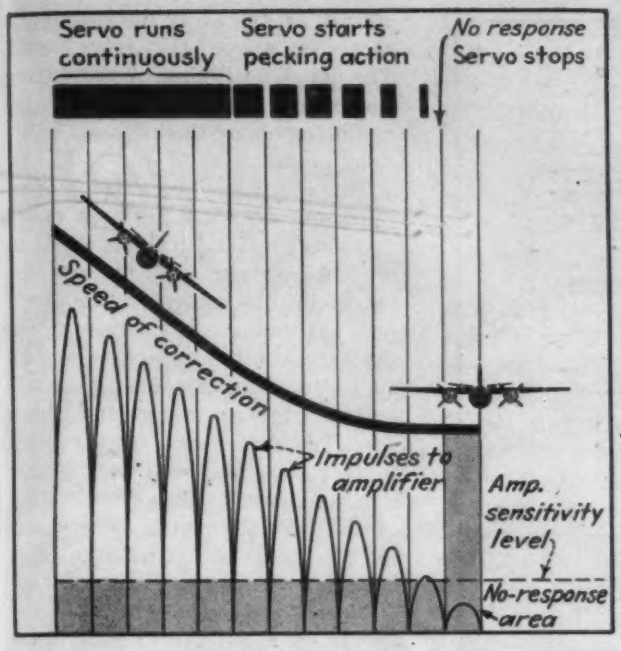

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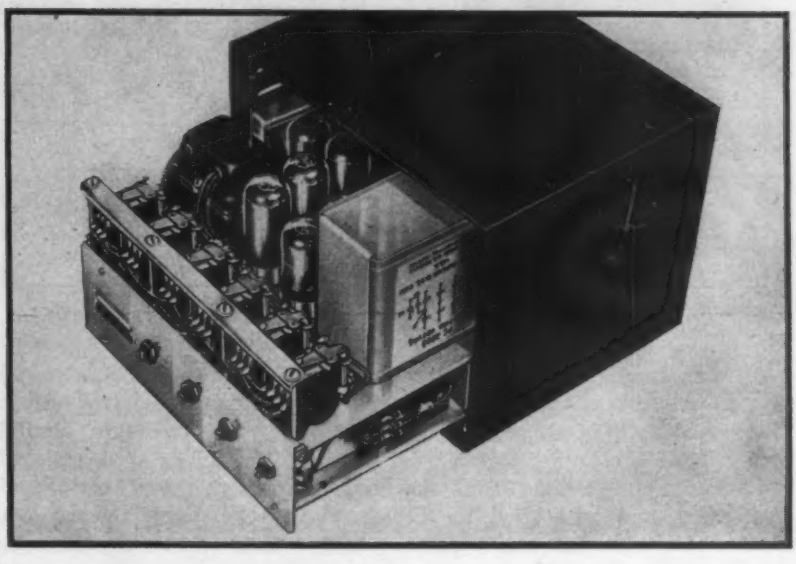

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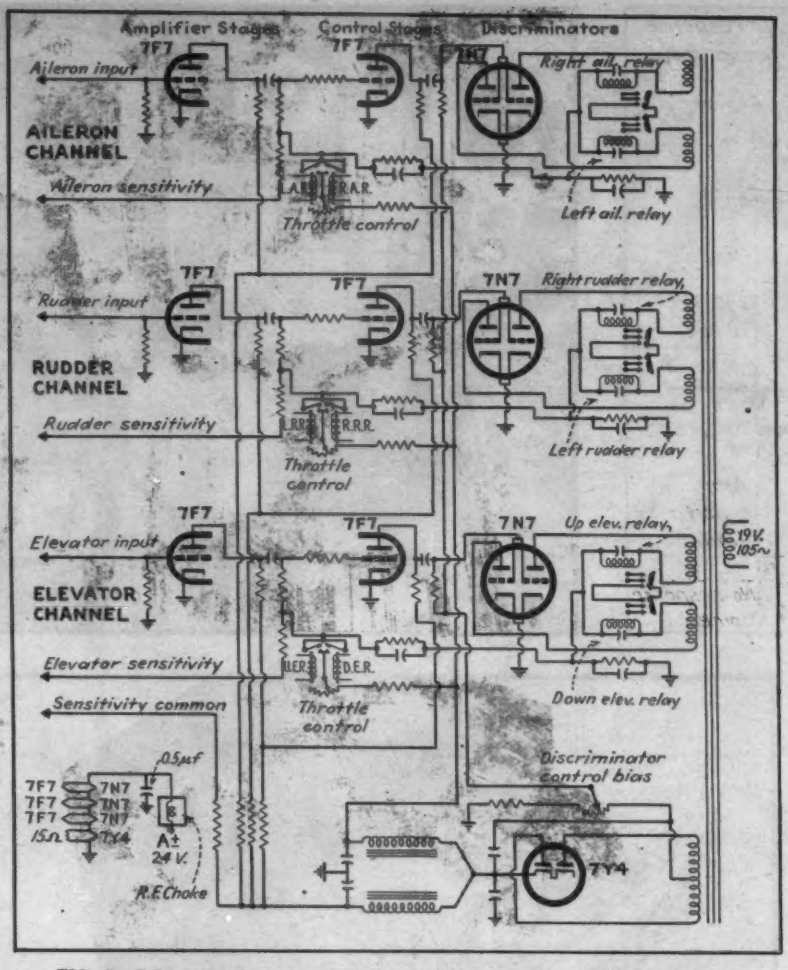


FIG. 5—Schematic diagram of 7-tube amplifier serving all three channels

the discriminator stage in such a way as to increase the sensitivity. This pulsating d-c feedback voltage is developed across a 500-ohm resistor in the plate circuit of the discriminator, and is applied to the control tube grid through a time-delay network that acts in conjunction with the third control voltage. When the sensitivity control is set at *A* and a weak a-c signal arrives, the feed-back voltage serves to increase the sensitivity of the control stage still more by shifting the bias point slightly to the left of *A*. This increases the amplifying effect of the tube, producing strong, firm closing of the proper relay in the discriminator plate circuit.

Pecking Action

The instant that a relay closes in the discriminator circuit, extra contacts on the relay apply the third control voltage, called *throttle voltage*, to the grid of the control tube. This throttle voltage is a positive d-c voltage obtained from the power pack, with its value being variable by means of a screwdriver-adjusted potentiometer on the amplifier chassis. The effect of throttle voltage is to move the operating point of the tube upwards toward *B*, decreasing the size of the plate current variations resulting from the given input signal. The tube continues to operate here until, as the servo unit gradually balances the bridge circuit, the a-c signal diminishes to the point where the discriminator relay opens. This removes the throttle voltage and the operating point moves back toward *A*. Now the signal is strong enough to close the relay again, but this time only for an instant because the throttle voltage is again applied to the tube to block the signal. Thus, the relay is made to open and close repeatedly, causing intermittent servo operation as the balance point is approached.

The rate at which the relay opens and closes is determined by the R-C time-delay network in the feedback circuit, as well as by the size of the capacitor across the relay itself. The net effect is that of preventing the signal from closing the relay again for about 15 cycles after the relay opens.

The resulting intermittent operation of the servo unit is called "pecking" action. Its purpose is to prevent over-control of the airplane by making the controls move slowly into position as the balance pot in the servo unit approaches its balance point. The amount of control surface movement during each "peck" is determined by the relay contact gaps, the relay spring tension, and other factors. The setting of the throttle control determines the amplitude of the smallest signal that will cause continuous operation of the servo unit, while the setting of the sensitivity control determines the signal amplitude below which servo motion stops entirely. The effects of these controls on the speed of flight correction are illustrated in Fig. 4.

Combined Amplifier Circuits

The complete circuit for the three amplifier channels and the power pack of the autopilot (integral in one small chassis) is given in Fig. 5. Parts values for the elevator and aileron channels are essentially as given in Fig. 3 for the rudder channel. Filament power is obtained directly from the 24-volt aircraft storage battery, while 19-volt, 105-cycle power to energize the primary of the power transformer is obtained from a small rotary inverter operating from the storage battery. Connections at the left in Fig. 5 go to the a-c bridge circuits for the respective channels and to the manual adjustments provided for use by the pilot. The relays at the right all control solenoids actuating the clutches and brakes in the servo units.

Servo Motor Units

The servo unit used to supply the mechanical force to the control surfaces for each channel consists of an electric motor driving a cable drum through a gear-reduction system and a reversible differential assembly incorporating solenoid-actuated friction clutches and brakes. The cable drum is connected to its control surfaces by ⅛-inch flexible

steel cables which attach to the main control cables of the plane.

The shunt-wound 1/20-hp d-c motor in each servo unit operates directly from the aircraft storage battery, and runs continuously in the same direction while the autopilot is in operation.

The power transmission system that couples a servo motor to its cable drum is illustrated in Fig. 6. The motor pinion *A* meshes with clutch gear *B*, which in turn drives clutch gear *C*. Each of these gears has a cork insert on the side away from the motor. The gears rotate continuously in opposite directions while the autopilot is in operation.

The clutch gears rotate on ball bearings which are fitted to two parallel operating shafts, *D* and *E*, in such a way that the ball bearings and gears are free to slide a limited distance along the shaft. The shafts in turn are free to slide endwise in their bearings in the servo unit frame.

Autopilot control panel, mounted within convenient reach of the pilot. With the autopilot in control at any given altitude, the plane can be maneuvered by fingertip adjustment of the turn-control and elevator knobs or by similar remotely located knobs near the bombardier

Firmly attached to each operating shaft is a clutch-and-brake disk (*F* and *G*) which has two flat friction surfaces. One surface faces the cork insert in the adjacent clutch gear and the other faces a similar cork insert (*H* and *I*) in the brake ring fastened to the servo unit frame.

Also firmly attached to the operating shafts are gears *J* and *K* respectively, which mesh with differential drive gears *L* and *M*. The gears rotate freely on the differential shaft, one on each side of the differential crosshead which supports the two crosshead bevel pinions. Rotation of the crosshead is transmitted to the cable drum through the cable-drum pinion.

Between the clutch gears and their adjacent clutch-and-brake disks are coil springs *N* and *O*, which press the ball-bearing housings of the clutch gears in one direction against clutch arms *P* and *Q*, and press the operating shafts *D* and *E* in the other direction against brake arms *R* and *S*.

Two brake solenoids, *T* and *U*, one on each side of the motor, operate pullrods which compress brake tension springs *V* and *W*. The tensions of these springs, applied through brake arms *R* and *S* to the ends of the operating shafts, force the brake surfaces of the clutch-and-brake disks against their cork-faced brake rings.

Two operating solenoids *X* and *Y* apply pressure through pushrods against clutch arms *P* and *Q* whenever the operating solenoids are energized. The clutch arms force the rotating cork-lined clutch gears against the clutch-and-brake disks.

Working Sequence of Servo Unit

Operating solenoids are energized individually by the closing of relays in the amplifier. In series with each operating solenoid is a cam-operated limit switch which prevents the servo unit from driving the control surfaces against their mechanical stops. A 0.5-μf capacitor in parallel with each solenoid-switch combination prevents arcing of the relay contacts.

The balance pot, by balancing out the original deviation signal, controls the amount of cable-drum rotation resulting from a given deviation of the airplane. Its wiper is fastened to the cable drum by means of a friction clutch that facilitates centering the wiper at the electrical center of the pot when the control surface is in normal flight position.

As soon as the autopilot master-switch is turned on, the motors in all three servo units begin to run. Each motor drives its two clutch gears in opposite directions. These gears rotate freely on their operating shafts and no motion is transmitted to the clutch-and-brake disks which are in their neutral positions. Therefore, the cable drum can be rotated freely even though the motor is running, and the servo units will not interfere with manual operation of the controls until the pilot engages the servo brakes.

After the servo brakes have been engaged the operation of the servo unit takes place in the following

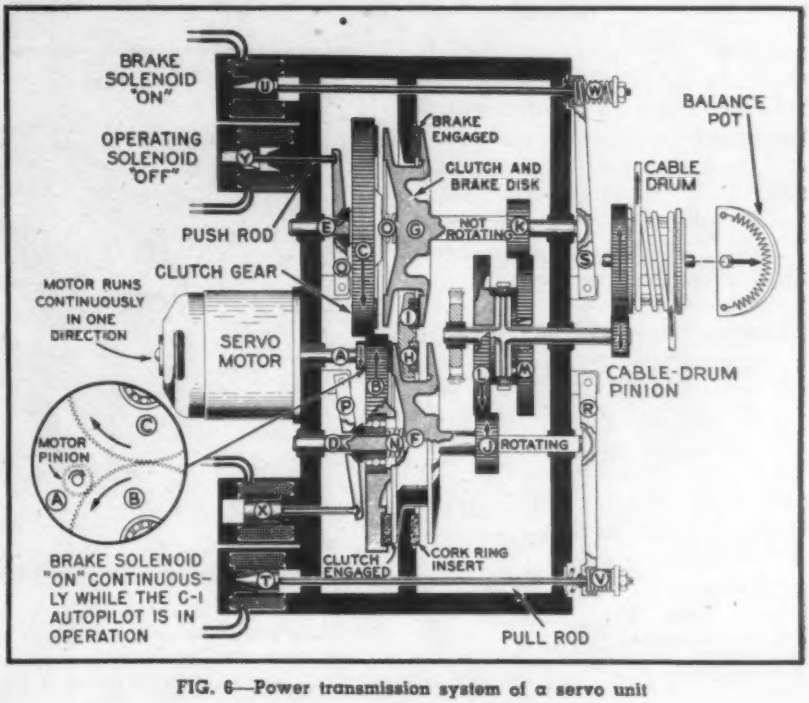
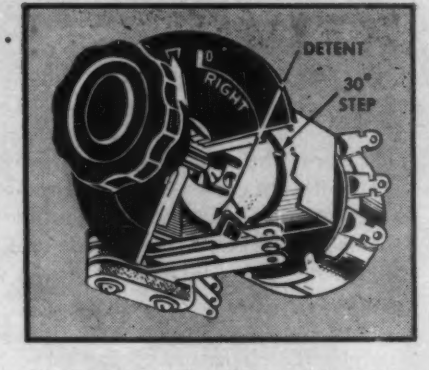


FIG. 6—Power transmission system of a servo unit

manner: When an a-c bridge or pilot-operated control transmits a signal to an amplifier, calling for movement of a particular control surface, the amplifier channel responds by closing one or the other of its two relays. The relay contacts then complete a d-c power circuit that energizes the correct operating solenoid in its servo unit. This causes the solenoid plunger and push-rod to move in against the clutch arm, which in turn forces the constantly rotating cork-faced clutch gear against the clutch surface of the clutch-and-brake disc. Continued inward movement of the clutch arm moves the entire clutch-and-brake disc assembly lengthwise, compressing the brake tension spring and forcing the brake surfaces apart.

As soon as the brake surfaces are



Construction of the turn control, showing the on-course detent in the cam and the 30-degree step in the cam to caution the pilot making turns requiring steeper banks

separated, the operating shaft is rotated by the clutch gear and transmits its motion to the differential gear assembly. The operating solenoid thus engages the clutch and releases the brake with the same motion, insuring that the cable drum will start instantly without slipping back during the engaging process.

Since only one operating solenoid is energized at any one time, the above-described condition will prevail on only one side of the servo unit, depending upon which of the two relays in the amplifier channel was closed. The other gear train will remain with its brake engaged, so that while one side of the differential is being driven, the other side is held firm. Energizing of the other operating solenoid causes reverse rotation of the cable drum.

At any time the human pilot may open the engaging switch on the autopilot control panel, and thereby release both brakes in the servo unit. When both brakes are released, the operating solenoids cannot cause cable drum rotation because the differential is free to idle.

Turn Control

While the airplane is flying under autopilot control, the pilot or bombardier can maneuver the airplane to make a properly coordinated turn. This is done through the turn control incorporated in the control unit. A corresponding but separate control is provided for operation of the airplane from a remote location by the bombardier or flight engineer.

The turn control consists of a knob-operated pot combined with a triple-contact spring-leaf switch, operated by a cam on the same shaft. This pot is connected into the aileron and rudder bridge circuits in such a way that any displacement of the pot wiper produces signals which result in coordinated movement of ailerons and rudder to produce a properly banked turn.

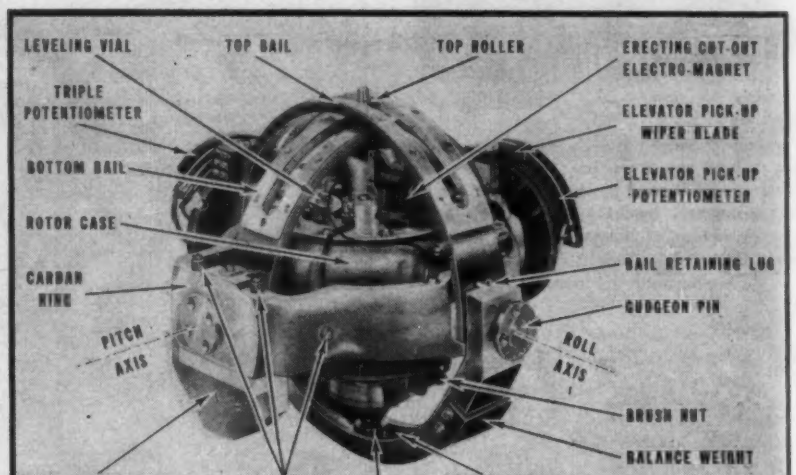
When the turn control knob is at the center position, the cam switch is open, but it closes when the control knob is moved in either direction to make a turn. Closure of the switch locks the directional gyro so that it cannot put in signals to oppose desired turning maneuvers.

Besides a detent which holds the knob at center and simultaneously opens the switch, other steps are provided on the cam to indicate the approach of the airplane to the maximum 40-degree banking limit inherent in the autopilot system. Humps are provided on either side of the detent to stop the free rotation of the knob at the zero point, so the pilot will be reminded to let the aircraft return to straight-and-level flight before he brings the knob back to the center to restore autopilot directional control.

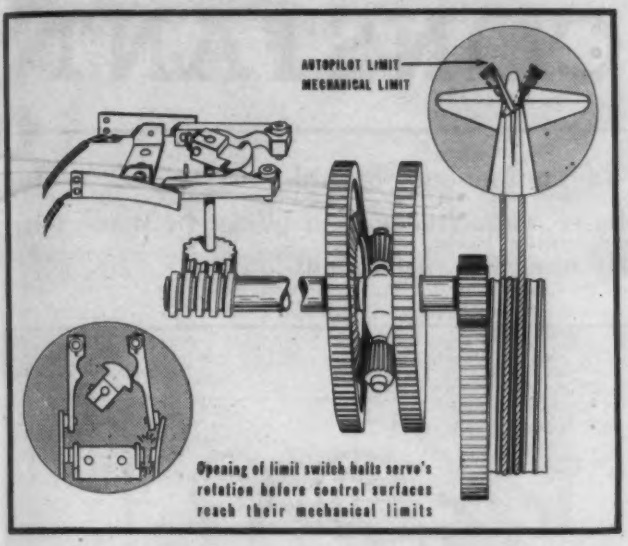
Adjusting the Centering Controls

Before engaging the servo units, the pilot must mechanically trim the airplane for straight-and-level flight. This establishes each servo balance pot wiper at a position corresponding to mechanical trim of its control surface. The pilot then adjusts each centering knob on the autopilot control panel to align the electrical balance point of each bridge circuit with this mechanical trim position of the balance pot wiper. After the engaging switches have been snapped on, the autopilot system, by always returning the balance pot wiper to its trimmed position, will keep the airplane in straight-and-level flight.

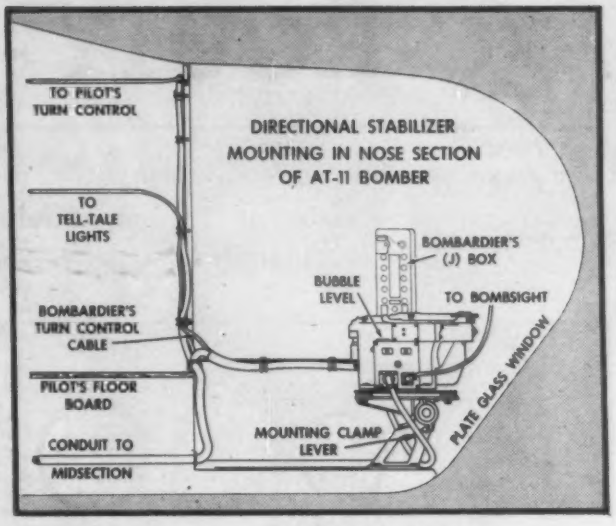
Directly above each centering control knob is a pair of indicating lights which are connected in



Vertical gyro of autopilot, with housing removed to show the erecting mechanism that keeps the gyro lined up with the pull of gravity despite rotation of the earth. The gyro rotor is a cup-shaped mass surrounding and driven by an electric motor in the center of the assembly


AUTOPILOT LIMIT
MECHANICAL LIMIT
Opening of limit switch halts servo's rotation before control surfaces reach their mechanical limits

Example of limit switch used to prevent a servo unit from jamming the control surfaces of the plane against their stops



This gyro detects off-course deviations and causes potentiometers to produce signals calling for the required maneuver

parallel with the operating solenoids of the corresponding servo unit. One light or the other of each pair is illuminated whenever the autopilot amplifier is calling for servo unit rotation, whether or not the servo unit is engaged. Thus, when the pilot is engaging the autopilot to the airplane, the illumination of either tell-tale light indicates that the balance point of the bridge circuit is not lined up with the trim position of the balance pot wiper, and further adjustment of the corresponding centering control is required.

Example of Operation

A step-by-step description of the action of the autopilot in correcting a pitch-axis deviation will give the simplest fundamental principles involved in correcting deviations, for no aileron or rudder movements are required for pitch axis deviations.

When the airplane is in straight-and-level flight, the elevator pickup pot in the gyro is at its normal position and the balance pot of the elevator servo is centered, holding the elevator control surfaces in their normal, level-flight position. Under this condition the bridge circuit is balanced and no correcting signal is applied to the amplifier.

Assume now that a sudden air current raises the nose of the airplane. The gyro case and its attached elevator pickup pot tilt with the plane, causing displacement of the pot wiper and unbalancing of the bridge circuit, with the result that a correcting signal is applied to the elevator channel. This causes the down-elevator relay in the amplifier channel to close, sending a down-elevator impulse to the elevator servo unit. The servo unit responds by driving the elevator control surfaces downward by means of cables, thereby lowering the nose of the plane. The direction of rotation is such that the balance pot wiper on the servo unit approaches a position where the bridge circuit will again be balanced.

As the airplane begins to level off, the pickup pot in the vertical-flight gyro begins to return to its normal position. At some intermediate position the bridge circuit will again become balanced and the down-elevator relay will be released. At this point the servo cable drum will stop, with down-elevator still applied.

It is now necessary to return the control surface to neutral to prevent over-control. This is achieved automatically because as the plane continues leveling off, the gyro unbalances the bridge circuit in the opposite direction. Now the up-elevator relay closes, resulting in opposite rotation of the servo unit and upward movement of the elevator, back toward its normal level-flight position. This principle is basic in aircraft control; after a correction has been applied by moving a control surface away from its normal position, the control surface must be returned to normal again.

As the airplane approaches level flight attitude, the speed of control-surface movement is gradually reduced by the autopilot. By the time the airplane reaches its normal level-flight attitude, the bridge circuit is again balanced, this time with all pots electrically centered, and the autopilot action ceases. The separate steps described above actually take place in a gradual progression, each movement blending into the next to produce smooth correction that may be rapid at first, but which tapers off smoothly as the plane resumes its normal flight attitude.

Commercial Future of Autopilot

In announcing the development of the C-1 autopilot and the electronic turbo regulator system described in May 1944 ELECTRONICS, W. J. McGoldrick, vice-president in charge of aeronautical engineering for Minneapolis-Honeywell Regulator Company, pointed out that these electronic controls take over some of the duties of the flight crew and enable the pilot and flight engineer to perform their work more effectively in the rarefied air of the upper atmosphere. Planes like the B-29 become easy to fly despite their huge size and weight, indicating an important role for these electronic controls in passenger and freight Stratoliners of the future.

CIRCUIT-CONSTANT

For experimental work involving the use of components of unknown value, useful measurements of resonant frequency, inductance, capacitance, and Q can be made with this portable, conveniently operated instrument

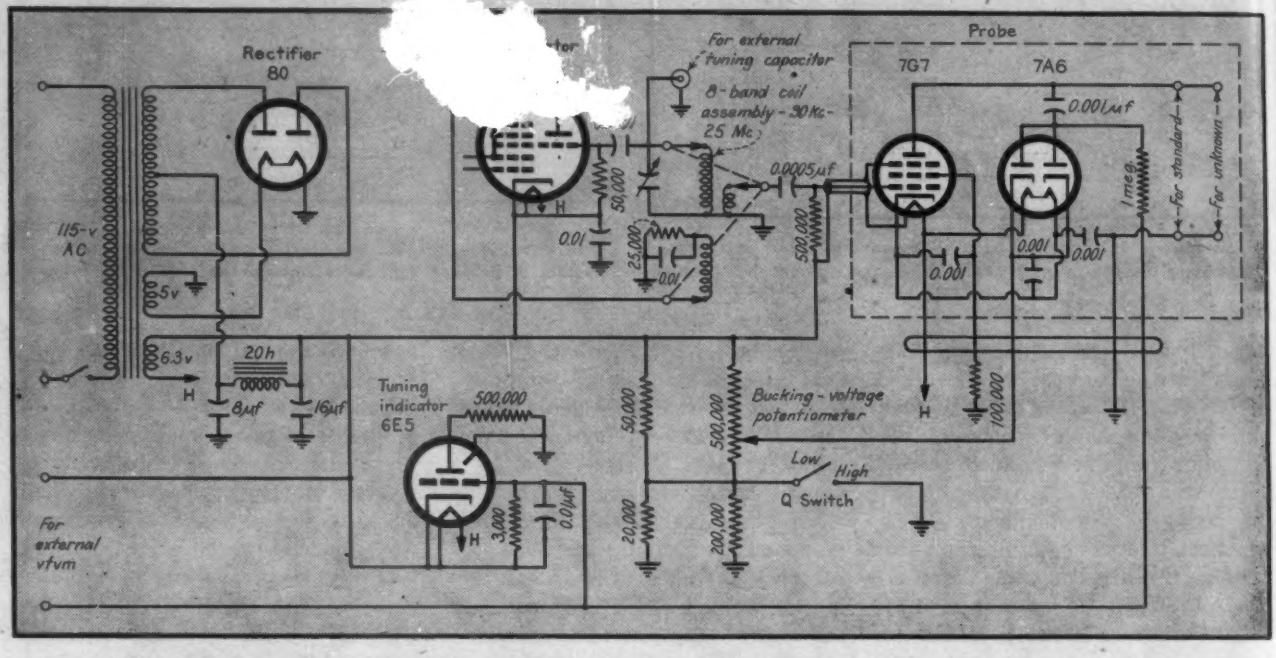


FIG. 1—Wiring diagram of the circuit-constant checker. Resonant tank for capacitance measurements and capacitance standard for inductance measurements are interchangeably connected to probe binding-posts at right

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IN experimental work where values of existing parts are altered to fit new needs, the writer has found use for a small portable instrument that will rapidly measure quantities such as resonant frequency, inductance, capacitance and Q.

Basically, the instrument to be described uses the resonance method of measurement. As diagrammed in Fig. 1, the unit is composed of a calibrated oscillator (90 kc-25 Mc) driving a pentode amplifier. For practical purposes, the amplifier can be considered a constant-current generator in which the developed resonance-voltage is proportional to the Q of the load. The amplifier and accompanying diode are mounted inside a probe, illustrated in Fig. 2.

A panel control is provided on the checking unit itself to introduce a bucking potential to the diode in slide-back-voltmeter fashion, although no absolute voltage measurements are made. When the bucking potential is equal to the peak r-f voltage, zero bias appears on the grid of the 6E5 tuning indicator which is thus made to just close at resonance over a wide range of load Q. In addition a spst toggle-switch is provided to reduce the bucking voltage to 71 percent of its initial value, which permits determination of the off-resonance points where the developed voltage has dropped to 71 percent of maximum resonance value.

Design Considerations

Selection of tubes for use in the probe amplifier is a compromise between shunt capacitance and g_m. High-frequency tubes materially reduce capacitance, but develop insufficient voltage across low Q circuits.

The positive terminal of the instrument power-supply is grounded. This conveniently permits the cold end of the resonant circuit to be at ground d-c potential. An original model used an a-c/d-c type of power supply, but the lack of line isolation was found to be highly undesirable.

Panel binding posts are provided for connecting an external vtvm to the probe diode for more accurate Q measurements. Also, there is provision for connecting to the oscillator tank circuit an external variable capacitor for making small incremental changes in frequency. This is useful in testing frequency-discriminator circuits.

Operating Procedure

In determining the resonant frequency of a tank circuit, the tank is

CHECKER

The circuit-constant checker. At the left are the tuning indicator, band selector, connections for external vtvm, and bucking-voltage potentiometer. Below the large oscillator-tuning control are the on-off and the Q switch. External tuning-capacitor receptacle is at the right

connected across the measuring terminals of the probe and the oscillator is adjusted for resonance as indicated by the 6E5. Since the pentode will act as a frequency multiplier, resonance will be indicated at sub-harmonics of the tank fundamental, but this is not objectionable because the developed tank-voltage is always greater at the fundamental frequency. Also the fundamental is the highest frequency at which any voltage can be developed.

Capacitance can be measured by connecting a standard tank and the capacitor to be measured across the measuring terminals. When the oscillator is adjusted for resonance $C = 1/\omega^2 L$ where C is the total tank capacitance. The capacitance scales should preferably utilize the two lowest frequency bands. The low end of the calibration is sufficiently spread to allow capacitance measurements to be made on video amplifiers, while the upper limit is about 100 $\mu\mu$f. With the particular oscillator ranges used, a 456-kc i-f transformer with an additional shunt capacitance serves as a standard tank.

The i-f transformer padder is utilized as a zero positioner for the capacitance scales. It is advisable to calibrate the capacitance scales against a standard Q meter or some other capacitance standard, rather than by computation based on the inductance and total capacitance of the standard tank.

Inductance measurements are made in a similar manner by using a fixed capacitance standard. With a 387 $\mu\mu$f standard and the 13 $\mu\mu$f residual probe capacity, the formula for L simplifies to $L = 63.2 \times 10^6/f^2$ where f is in kc and L is effective series inductance in μh. The effective series inductance may differ from the true inductance by less than 2 percent for coils having less than 10 $\mu\mu$f of distributed capacitance. The inductance range is 1μh to 9 mh.

Determinations of Q can be roughly made by using the frequency-variation method. If the coil is shunted by an air capacitor

$$\text{Coil } Q = \left(\frac{F_r}{F_r - F_0}\right)\left(\frac{F_0}{F_r + F_0}\right)\left(\sqrt{\frac{E_r^2 - E_0^2}{E_0^2}}\right)$$

where F_r and E_r are the resonant frequency and voltage respectively and F_0 and E_0 are the off-resonant frequency and voltage respectively.

When $E_r/E_0 = \sqrt{2}$, as is the case when using the instrument Q-switch —and also assuming that the first two terms of the equation above are equal to $\frac{1}{2}F_r/(F_r - F_0)$—the equation simplifies to $Q = F_r/\Delta f$ where Δf is the frequency difference between the points at which response is down to 71 percent. The above assumption contributes error at low Q values, but it is less than the accuracy of measurement. It is best to find Δf by multiplying dial-division difference by kc per division for the particular portion of the dial used. For very high Q values, this method again becomes approximate because of the inability of determining Δf closely enough and also because of the finite dynamic plate resistance of the pentode amplifier and diode.

These Q measurements are simple but, at best, they are quite rough. When greater accuracy is desirable, the reactance-variation method is recommended. Still other measuring methods will suggest themselves, based on a high-impedance r-f source.

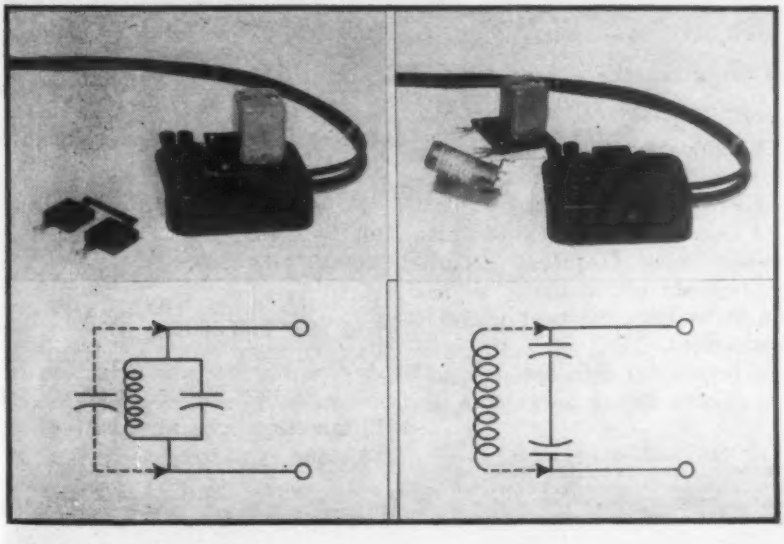

FIG. 2—Probe, which is permanently connected to checker proper, is shown at left equipped with resonant tank for capacitance measurements and at right with capacitance standard replacing tank, and inductance in place for checking

Frequency Allocation for M

This method for assigning channel frequencies takes into account the response of the filter circuits, and cross-talk due to channel proximity. It provides the same electrical performance on all channels, and distributes the channels so that harmonic interference is minimized

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THE problem arises, in many radio-electronic applications, of selecting the frequencies to be assigned to each of a group of frequency-selective control circuits so that the total cross-talk due both to adjacent-channel proximity and to system distortion does not exceed a prescribed value.

A usable frequency distribution plan could be obtained by experimentally trying different frequency combinations, or by empirically arranging selectivity response curves for each channel on a frequency scale until a satisfactory compromise arrangement were obtained. The first method has obvious utility only when the number of channels is small, whereas the second provides no information regarding the effect of system distortion.

In the event that all channel filters are of the same type and have similar Q factors, as is commonly the case, a solution can be developed based upon an analytic allocation plan which will provide equal electrical performance on all channels and from which the problems arising from operation of any number of channels can be solved.

Logarithmic Distribution

Just as the frequency response of each of a series of selector filters of equal electrical characteristics but different channel frequencies can be written by identical equations when expressed in percents of their respective channel frequencies, so if the frequency separation between successive channels can be written by identical equations, each channel will be as well situated electrically as any other. If the percent frequency separation between channels is constant, such identical equations can be written. The requirement that no one channel be favored over the others in its separation allotment is fulfilled if separation be based on a constant percent of the mean of the respective channel frequencies. That this is so will become more apparent when the expressions for band allocation are derived.

It will be shown that a logarithmic distribution provides this constant mean-frequency separation.

Let:

n = channel number, where channels are numbered consecutively from 1 to N starting with the lowest-frequency channel

f_n = frequency of any specific channel number n

f_{max} = frequency of highest-frequency channel, numbered N

f_{min} = frequency of lowest-frequency channel, numbered 1

m = slope constant, defined by the following:

$$n = 1 + m \log (f_n/f_{min}) \quad (1)$$

$$dn = m(df_n/f_n)\log_{10} e = 0.434m(df_n/f_n) \quad (2)$$

Rewriting Eq. (2),

$$dn/df_n = 0.434m/f_n \quad (3)$$

This equation states that channel separation is related to the channel frequency by a constant. That is, a logarithmic allocation plan provides mean frequency separation between all channels, as has been shown to be the most desirable arrangement.

To obtain suitable design equations it is necessary to evaluate the slope constant, m, and obtain general expressions for any channel frequency and for the channel separation.

If dn is made equal to unity, Eq. (2) reduces to

$$df_n/f_n = 2.303/m \quad (4)$$

Writing the general Eq. (1) for the particular channels $n1$ and $n2$ where the 1 and 2 indicate different channels, $n2$ being higher than $n1$ but in no other way specifying the location of these two channels in the frequency spectrum, the following expressions are obtained:

$$n1 = 1 + m\log(f_{n1}/f_{min}) \quad (5)$$

$$n2 = 1 + m\log(f_{n2}/f_{min}) \quad (6)$$

$$n2 - n1 = m\log(f_{n2}/f_{n1}) \quad (7)$$

$$m = \frac{n2 - n1}{\log (f_{n2}/f_{n1})} \quad (8)$$

Rewriting Eq. (1) in exponential form

$$f_n/f_{min} = 10^{(n-1)/m}$$

or

$$f_n = f_{min}10^{(n-1)/m} \quad (9)$$

Eliminating m between Eq. (8) and (9), and letting $n1 = 1$, and $n2 = N$

$$f_n = f_{min}\,10^{[(n-1)\log f_{max}/f_{min}]/N-1} \quad (10)$$

Eliminating m between Eq. (4) and (8), and evaluating as in Eq. (10)

$$\frac{df}{f} = \frac{2.303}{N-1}\log\frac{f_{max}}{f_{min}} \quad (11)$$

* All statements, opinions and assertions appearing in this paper are those of the writer and are not to be construed as official or reflecting the views of the Naval Department or the naval service at large.

Multi-Channel Systems

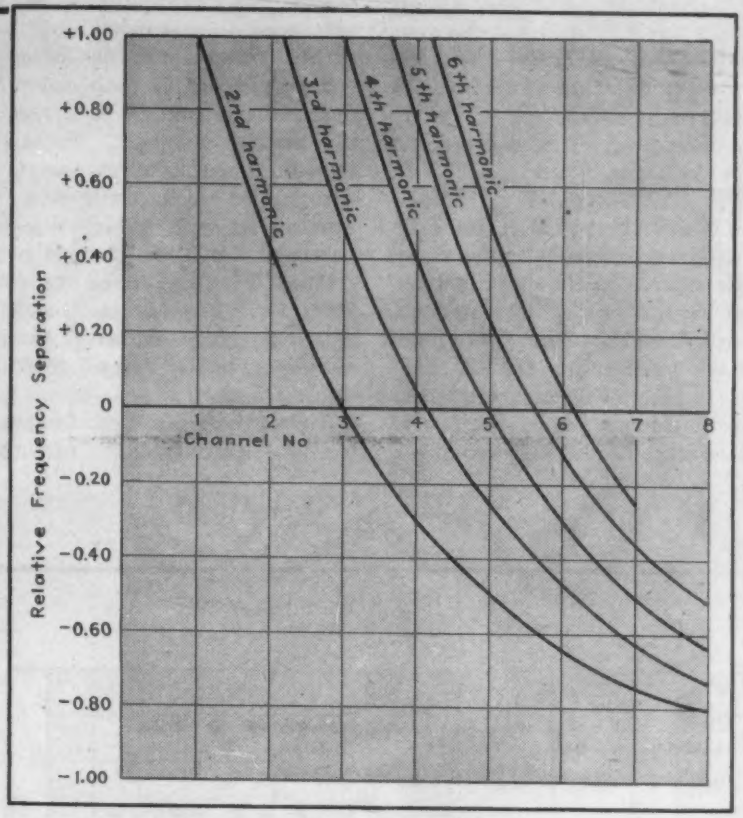

FIG. 1—When the ratio between successive channel frequencies is $\sqrt{2}$, the separation between a given harmonic of the lowest channel and any of the other channels is as shown. The graph can be used for harmonics of other channels by shifting the channel No. scale to the left

Equation (10) gives the frequency of any channel n as a function of the maximum and minimum channel frequencies and the number of channels to be contained within these limits. Equation (11) gives the mean channel separation in terms of the ratio of the highest to the lowest channel frequencies and the total number of channels.

Geometric Distribution

Allocation based upon a geometric progression is identical with results obtained by following a logarithmic distribution of channel frequencies. The logarithmic derivation has been presented because of the insight which it gives to the basic theory. However, because of the concept of channel multiplier which it introduces, the geometric derivation will also be briefly presented.

If the frequencies of the channels are in a geometric series the expression for any channel frequency is

$$f_n = f_{min} r^{n-1} \tag{12}$$

where r, the ratio in the geometric series, will be called the channel multiplier from its physical significance.

If Eq. (12) is written in logarithmic form,

$$\frac{\log (f_n/f_{min})}{\log r} = n - 1 \tag{13}$$

it will be recognized as equivalent to Eq. (1) where

$$m = 1/\log r \tag{14}$$

By following a procedure similar to that used to evaluate m in the logarithmic derivation, r can be evaluated.

$$r = 10^{[\log (f_{max}/f_{min})]/(N-1)} \tag{15}$$

The remainder of the derivation need not be reproduced. That the geometric and logarithmic plans of allotment are identical has been verified, and the concept of a channel multiplier has been introduced to replace the slope constant which arose in the logarithmic derivation.

Frequency Separation Between Harmonics

Having determined the plan by which channel frequencies will be alloted, it is next essential to examine the manner in which the harmonics of the channels will distribute themselves throughout the frequency spectrum. The channels can then be assigned frequencies both in accordance with the previous relations and also in such a sequence that interference in any channel from harmonics of the lower channels will be a minimum. Let:

h = the order of the harmonic
Δf = the separation between a harmonic and a channel
α_f = relative separation between channels
α_h = relative separation between a harmonic and a channel

Mathematically these terms are defined as follows:

$$\Delta f = h f_{n1} - f_{n2} \tag{16}$$

which is the frequency separation between the h order harmonic of the $n1$ channel, and the $n2$ channel itself. Relative channel separations then are

$$\left.\begin{aligned} \alpha_f &= \frac{f_{n-1} - f_n}{f_n} = 1 - \frac{1}{r} \text{ (higher channel)} \\ \text{or} \\ \alpha_f &= \frac{f_{n-1} - f_n}{f_n} = r - 1 \text{ (lower channel)} \end{aligned}\right\} \tag{17}$$

$$\alpha_h = \frac{\Delta f}{f_{n2}} = \frac{h f_{n1} - f_{n2}}{f_{n2}} = \frac{h}{(f_{n2}/f_{n1})} - 1 \tag{18}$$

but

$$\frac{f_{n2}}{f_{n1}} = \frac{f_{min}\, r^{n2-1}}{f_{min}\, r^{n1-1}} = r^{n2-n1} \tag{19}$$

therefore

$$\alpha_h = \frac{h}{r^{n2-n1}} - 1 \qquad (20)$$

In particular, if $n1$ equals the first channel, $r = \sqrt{2}$, and $n2$ assumes channel numbers from 1 to 8, the plot of Fig. 1 results.

Equation (20) gives the relative separation between the h harmonic of channel $n1$, and channel $n2$. However, it is not necessary to solve the equation for all possible combinations of $n1$ and $n2$. The single solution plotted in Fig. 1 suffices (for cases where $r = \sqrt{2}$). If, for instance, it is required to obtain the same information for the proximity of the harmonics of channel 2 to the other channels, shift the channel numbers one unit to the left. In this manner, the relative locations of the harmonics of all the channels can be studied.

To generalize Eq. (20) further it is necessary to eliminate the channel multiplier, which can be done as follows:

From Eq. (17),

$$r = 1/(1 - \alpha_f) \qquad (21)$$

From Eq. (20),

$$r = \left[\frac{h}{\alpha_h + 1}\right]^{1/(n2-n1)} \qquad (22)$$

Equating Eq. (21) and (22) and solving for α_h,

$$\alpha_h = h(1 - \alpha_f)^{n2-n1} - 1 \qquad (23)$$

General Harmonic Separation Curves

As in Eq. (20), if $n1$ in Eq. (23) equals the first channel and $n2$ assumes successive channel numbers, a plot results which, by proper manipulation of the channel axis, will give the information for all channels. It is only necessary to consider the harmonics of the lowest channel in the following discussion, the method of generalization being understood.

Equation (23) relates the frequency separation ratio between channels and harmonics for any order of harmonic and any number of channels. As this equation involves analytic relations, without reference to specific circuit properties, separate families of curves can be plotted for each order harmonic corresponding to a specified number of channels. These will then be general curves associating the channel to harmonic frequency separations with any of the channels and for each harmonic considered. Figures 2 and 3 are plotted from Eq. (23) for the second to fifth harmonics inclusive, showing curves applicable for up to fifteen channels.

To use these families of curves, a typical selectivity curve for one of

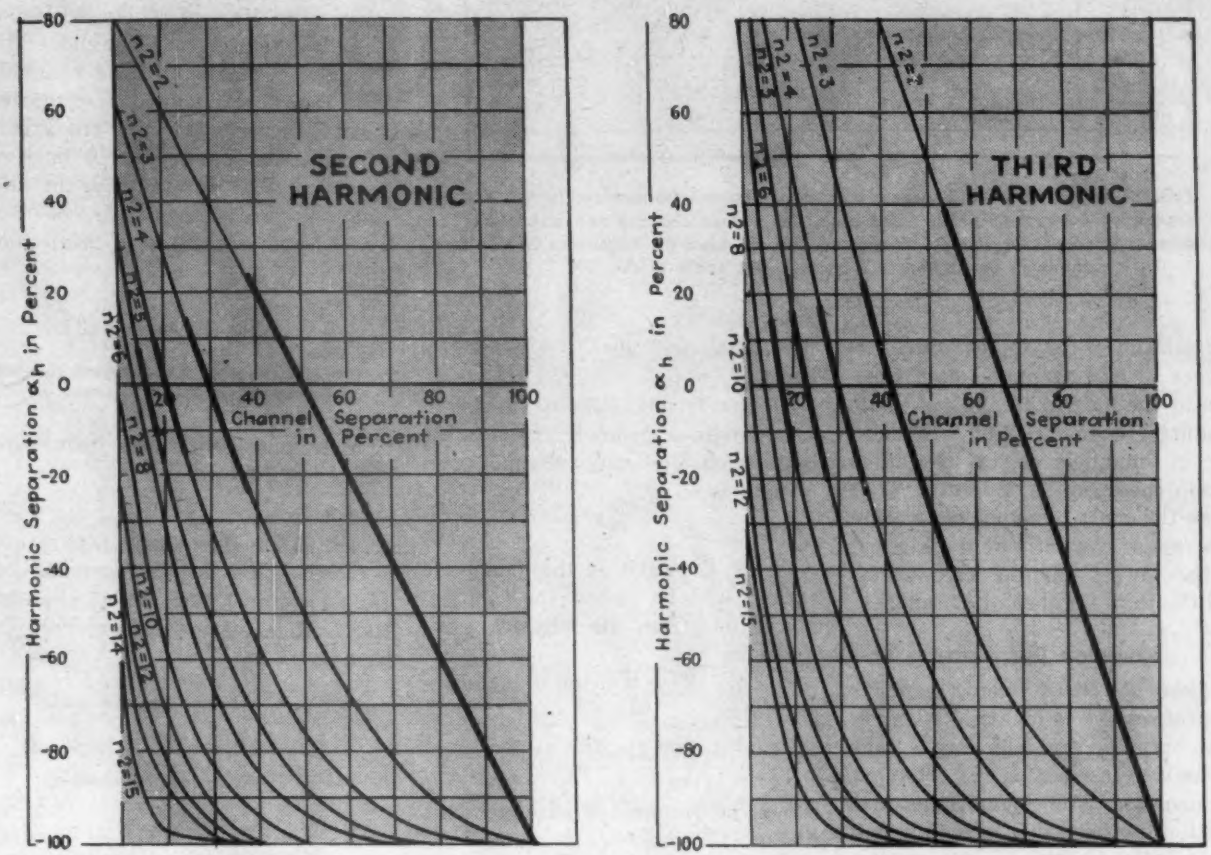

FIG. 2—General design work sheets showing the separation between a harmonic and the channels as a function of the separation of the channels themselves. Curves are plotted for systems up to fifteen channels; thus, the curve $n2 = 6$ is for a six-channel system. The heavy-line portion of each curve indicates the cyclic variation of the optimum channel separation

the channel filters is required. Figure 4, for example, may be used to illustrate applications of the method. Shown also in this figure are selectivity curves corresponding to 10 and 25 percent total distortion. The channel information is expressed in percent separation from the channel frequency for convenience in application of Eq. (23) or of the harmonic work sheets.

Example

For a system of ten channel selectors, a channel multiplier of 1.48, and a signal distortion of 25 percent second harmonic and 10 percent third harmonic, it is desired to know the maximum cross-talk on any channel resulting from adjacent-channel proximity and harmonic distortion. Figure 4 will be used as a typical selectivity characteristic for the channel filters.

The channel separation ratio determined from Eq. (17) for $r = 1.48$ is 32.4 percent and 48.0 percent respectively. Reference to Fig. 4 gives 6.5 percent (point A) and 8.5 percent (point B) cross-talk due to adjacent-channel coupling. These two values are for the two adjacent channels, one above and one below the channel under consideration. Referring to the harmonic families of curves on Fig. 2, corresponding to a 32.4 percent channel separation for a ten channel system the second harmonic will pass as close as 8.7 percent, and the third harmonic as close as 7.4 percent to the nearest channel, and on the low-frequency side. When these quantities are used in Fig. 4, it is found that for the above conditions the maximum cross-talk on the channel which is the most affected by second harmonic from a lower channel will be 32.2 percent (point C), and on the channel similarly affected by third harmonic will be 13.0 percent (point D). The cross-talk on the lowest channel will be 8.5 percent from the second channel proximity. On the second channel, cross-talk will be 6.5 percent from first channel proximity and 8.5 percent from third channel proximity. The third channel will be affected by second and fourth channel proximity, and by 32.2 percent second harmonic from the lowest channel. The fourth channel will have channel proximity cross-talk, and in addition third harmonic from the lowest channel, and second harmonic from the second channel. The maximum cross-talk which can appear on any channel, as obtained by taking the quadrature sum of all cross-talk terms, is $(6.5^2 + 8.5^2 + 32.2^2 + 13.0^2)^{\frac{1}{2}} =$

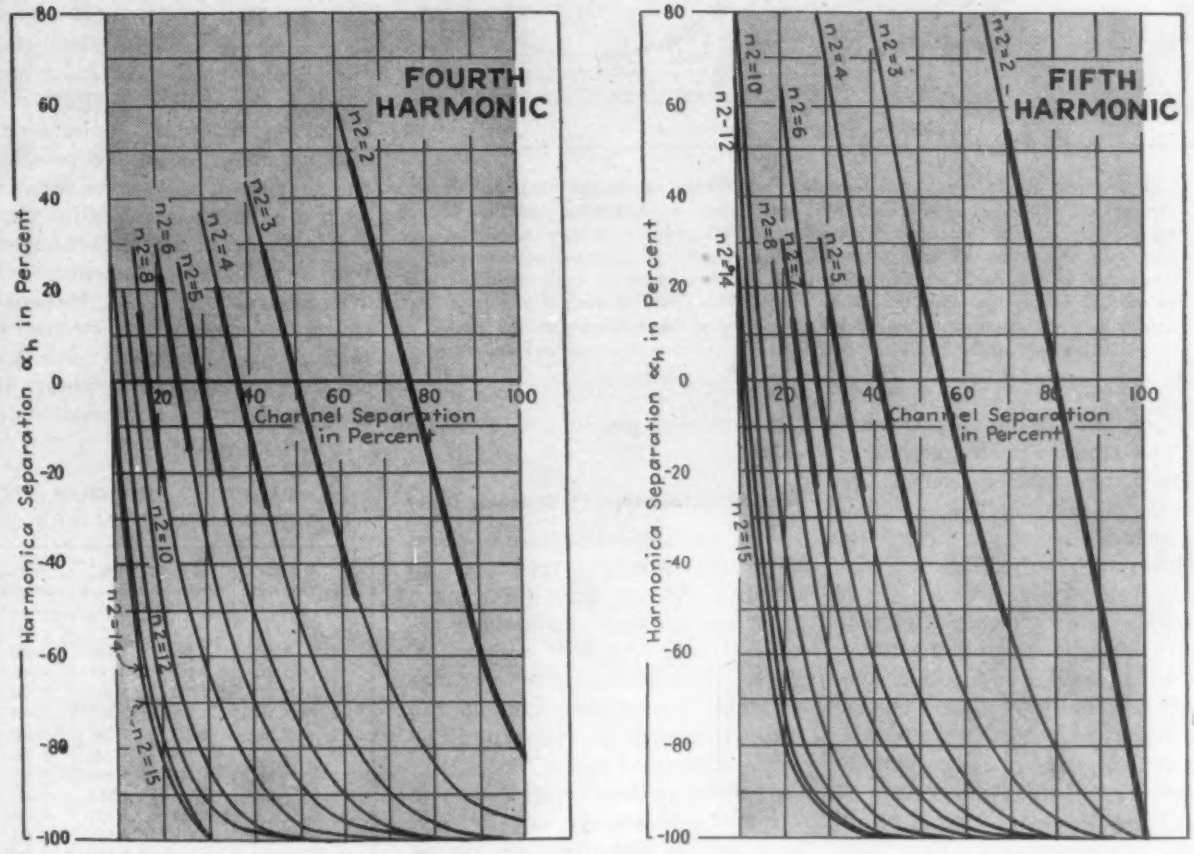

FIG. 3—These are the same type curves as in Fig. 2, but for higher harmonics. Over the heavy portion of each curve, harmonic to channel separation is small. Beyond the heavy-line regions, channel separation is either dangerously small or unnecessarily large. The end points of the heavy lines locate the optimum channel separations, a compromise between channel and harmonic interference

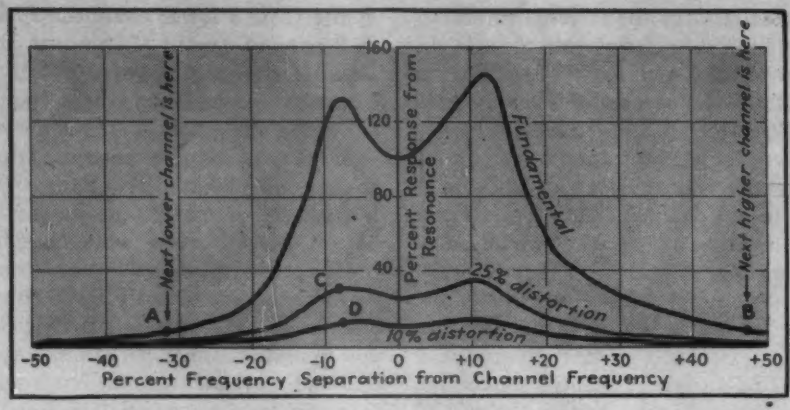

FIG. 4—Frequency response of the channel selector used in the illustrative examples. Instead of considering the distortion component as a percent of the signal, the response of the channel selector to the distortion is considered as a percent of the response to the signal. Response curves corresponding to 25 percent and 10 percent distortion are plotted on the same axis to facilitate cross-talk calculations

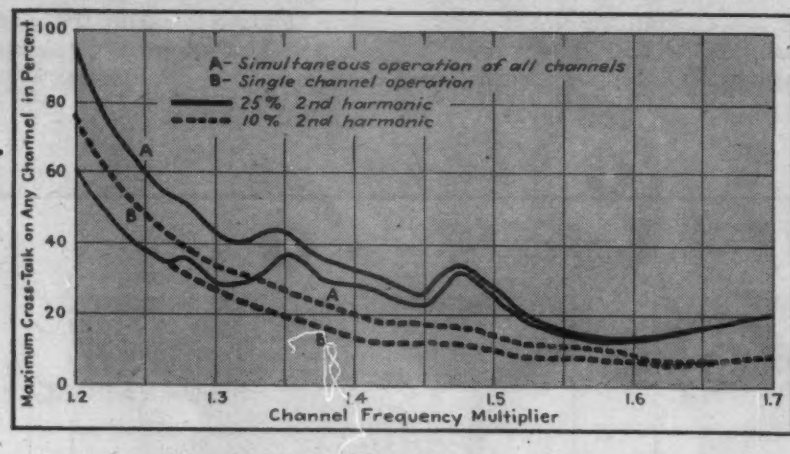

FIG. 5—From Fig. 2 and 3 the harmonic to channel separation for a given channel separation is determined. With this harmonic separation and Fig. 4, the percent harmonic cross-talk is determined. This plus the channel proximity cross-talk are combined and plotted against the given channel separation (converted to channel multiplier). Repeating this procedure for various values of channel separation gives the above graph. The utility of such a plot is in determining the channel multiplier which will give the minimum or the permissible cross-talk. The plot shown here is for a ten-channel system

36.4 percent, the maximum cross-talk the circuits must tolerate.

For a ten-channel selector, determine the maximum cross-talk on any channel as a function of the channel multiplier. The system may contain either 10 percent or 25 percent second harmonic distortion. This is a continuation of the above type of example but involves computation of the total distortion corresponding to various values of r. Figure 5 is a plot of the results obtained. From this type of curve the most suitable value of r can be selected by inspection. The ratio between the highest and lowest channel frequencies can then be computed by application of Eq. (12), thereby providing a complete solution.

Method if Response of Channels Differ

The examples involved a selectivity characteristic typical to all channels. Where these differ much from one another the method developed here can still be applied. Each channel selectivity response must be treated separately in the manner applied to the typical or average response curve.

If the Q of the circuits and their frequency responses vary widely, however, the allocation plan can be improved by compromising results of this method with the best performance reached by experimentally manipulating the channel frequencies. In extreme cases, it is conceivable that the latter procedure will prove most effective.

Optimum Channel Multipliers

In the process of utilizing the harmonic versus channel separation curves, it is evident that the ordinate erected at any channel separation value determines the relative frequency separation from the channel frequency for the particular harmonic involved. From these curves, it is therefore possible with the aid of a pair of dividers to determine the closest harmonic separation from any of the channels. Supplementary curves can thus be derived to designate this condition. The heavy lines of Fig. 2 and 3 show that part of the curves used to give this supplementary type of graph. An examination of such curves discloses the interesting fact that they vary cyclically, and for any harmonic there correspond specific allocation plans for channel frequency separations, which result in the greatest harmonic separation from any of the channels.

In the event the channel selectivity curves are symmetrical about the channel frequency, these operating points denote conditions for minimum cross-talk. Accordingly, the maximum amplitude points of the supplementary curves establish optimum frequency allocation plans, applicable to any filter-channel system employing elements with symmetrical selectivity responses. Optimum locations may be read directly from the curves. For purposes of tabulation, however, the accuracy may be improved by re-

TABLE 1 — OPTIMUM CHANNEL MULTIPLIERS

n	2nd Harmonic	3rd Harmonic	4th Harmonic	5th Harmonic
2	1.620	2.182	2.730	3.260
3	1.322	1.568	1.769	1.948
4	1.232	1.373	1.495	1.595
5	1.187	1.278	1.365	1.435
6	1.135	1.222	1.288	1.343
7	1.117	1.185	1.239	1.283
8	1.097	1.158	1.204	1.241
9	1.085	1.138	1.174	1.209
10	1.076	1.132	1.157	1.185
11	1.068	1.110	1.142	1.166
12	1.062	1.103	1.128	1.151
13	1.057	1.092	1.117	1.137
14	1.053	1.085	1.108	1.127
15	1.049	1.079	1.100	1.117

sorting to computation from a derived formula.

Maximum Harmonic Separation

Let α_{h1} and α_{h2} be the harmonic separation for any two successive channels. From examination of Fig. 2 and 3 it is seen that maximum separation of harmonics from channels occurs at

$$\alpha_{h1} + \alpha_{h2} = 0 \quad (24)$$

By applying Eq. (23) and manipulating, there results

$$r = [(h/2)(1+r)]^{1/N} \quad (25)$$

This equation can be solved on a log-log slide rule.

In Table 1 are optimum values for the channel frequency multipliers which yield minimum cross-talk due to any harmonic up to the fifth when applied to symmetrical selectivity characteristics. The number of channels being considered for use determines the number of valid channel multipliers available from the table. For example, if five channels are contemplated, all multipliers above row 5 in the table may be considered. All other values have no meaning. The table can be similarly interpreted for other numbers of channels.

Asymmetrical Channel Selectivity Response

If the frequency response characteristic of the channels is asymmetrical, a measurement can be made of the degree of dissymmetry. Correction factors can then be applied to Table 1 for conversion to the required optimum multipliers.

Referring to Fig. 6, the response dissymmetry coefficient can be defined as the ratio of the highest to the lowest frequencies which produce equal responses.

$$k = a/b \geq 1 \quad (26)$$

From Eq. (24) and (26)

$$\alpha_{h2} + k\alpha_{h2} = 0 \quad (27)$$

Substituting Eq. (23) into Eq. (27), and evaluating at $n1 = 1$ and $n2 = N$,

$$h(1-\alpha_f)^{N-1} - 1 + k[h(1-\alpha_f)^N - 1] = 0 \quad (28)$$

From Eq. (21)

$$(1/r)^{N-1} + k(1/r)^N = (1+k)/h \quad (29)$$

$$(1/r)^N(k+r) = (1+k)/h \quad (30)$$

$$r^N = h(k+r)/(1+k) \quad (31)$$

When $k = 1$ (i.e., the response is symmetrical about the channel frequency),

$$(r_{h-1})^N = h(1+r)/2 \quad (32)$$

When k is not equal to 1,

$$(r_{a/b})^N = h(k + r_{a/b})/(1+k) \quad (33)$$

Letting $r_{a,b}/r_{h=1} = \beta$, the ratio of the optimum channel multiplier for asymmetrical channel response to the optimum multiplier for symmetrical response, and writing $r_{a,b} = \beta r_{h=1}$ and dropping the subscript $k = 1$,

$$\beta = \left[\frac{2(k+\beta r)}{(1+r)(1+k)}\right]^{1/N} \quad (34)$$

Here β is the correction factor to be applied to the optimum channel multipliers of Table 1. Figure 7 shows correction factors for asymmetry coefficients from 1.0 to 1.5.

From Table 1 and Fig. 7, the channel multipliers giving the least cross-talk from any harmonic up to the fifth can be identified, taking into account the shape of a typical channel response curve and the number of channels.

Conclusions

A desirable choice of frequency assignment to the elements comprising a group of frequency-selective circuits appears to be based upon a constant percent frequency separation plan. This is predicated upon the condition that the circuit Q factors for the various elements are substantially alike. For this condition all channels will have identical electrical performance properties, which is normally desirable in connection with the use of frequency-selective circuits.

Separation on a constant mean percent frequency basis can be realized by utilizing a logarithmic or geometric progression plan of allocation.

A method has been developed with working equations and general curves which provides a means for solving all important problems associated with such an allocation plan, provided, however, that knowledge of the selectivity responses for the selector channels is available.

Optimum allocation plans which minimize cross-talk resulting from any harmonic are related to the degree of response dissymmetry. These can be identified for any particular problem by means of derived general expressions or the plotted work sheets.

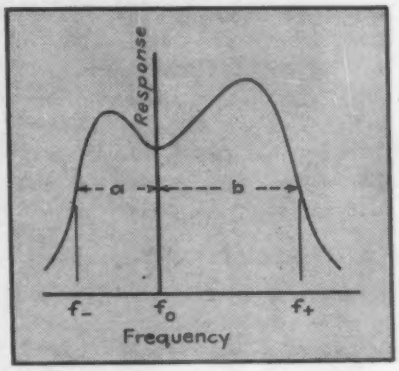

FIG. 6—Where the dissymmetry of the channel-selector filters is great a correction is introduced. The ratio of a to b is the dissymmetry coefficient of the channel-selector response curve

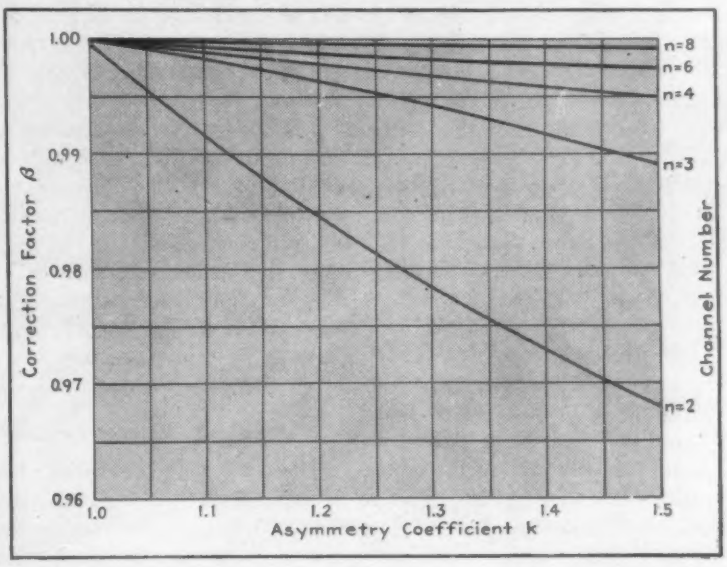

FIG. 7—To correct for selector response dissymmetry the factors given above for asymmetry coefficients through 1.5 and channels up to eight are applied to the optimum channel multipliers given in Table 1

Open-Grid Tubes in Low-Level Amplifiers

By ROBERT J. MEYER
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FOR CERTAIN APPLICATIONS in amplifiers requiring a high input resistance and low noise level it has been found desirable to eliminate the grid leak, and no undesirable effects resulted from using the tubes in this manner. Examples of such applications are amplifiers operating from a low-level, high-impedance source, amplifiers that must present the smallest possible load to the preceding stage, and amplifiers that must handle signal voltages of the same order as the noise level. Actually, operation of a tube with an open grid is less noisy than operation with a grid leak.

Problems To Be Overcome

Different objections to the use of open grid tubes can be summed up as follows:

(1) It has been suggested[1] that if the operating temperature of the tube is high enough, the grid will emit electrons. When this occurs in a conventional circuit, the resulting current through the grid leak (generally a resistance of about 2 megohms connected between grid and cathode) will make the grid less negative and increase the space current, thus increasing the temperature. If the grid becomes positive, electrons flowing to it will increase the grid temperature and might produce secondary emission. The grid will continue to become less negative as long as the number of electrons leaving the grid exceeds the number entering. This process is cumulative and may result in damage to the tube. The process might be aided initially by the flow of positive ions to the grid when it is negative. This effect would be most pronounced in a soft tube. It has been asserted that the use of extremely high cathode-to-grid resistance (such as an open grid) would tend to aid the process by producing large voltage drops in the grid circuit.

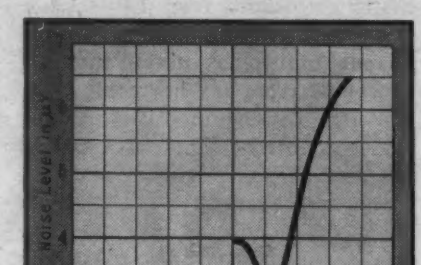


FIG. 1—Noise level vs. cathode-to-grid voltage for a 6SJ7 tube connected as a triode, with 40 μμf in the grid circuit to simulate a high-impedance crystal pickup having no shunt resistance

(2) If the grid leak is omitted, electrons will flow to the grid from the cathode and the grid will accumulate a negative charge.[2] Then any slight change in the grid capacitance would change the grid potential and produce fluctuations in the plate current.

(3) There is a small current flowing between the cathode and the grid through the leakage paths. However, these leakage paths are continually changing and thus there is a random fluctuation in the grid leakage current which produces noise in the tube. This effect should be most prominent during the time when the tube is heating.

Noise in Amplifier Circuits

The three principal types of noise in an amplifier circuit are flicker, shot effect and thermal agitation. These noises can be considered as being developed by equivalent generators in the grid circuit of a noise-free tube.

The flicker voltage, which is produced by irregularities in the temperature of the heating element, is inversely proportional to the square of the frequency.

Shot noise is uniformly distributed throughout the frequency spectrum, independent of the electron velocity and independent of the manner in which the total current divides between the electrodes. The values of the shot voltage E for triodes can be calculated from the formulas[3]

$$|E| = 2 \times 10^{-10} \sqrt{\Delta F / g_m} \qquad (1)$$

For pentodes, the formula is

$$|E| = \frac{2 \times 10^{-10}}{g_m} \sqrt{\frac{I_b}{I_b + I_{c2}} (g_m + 8 I_{c2}) \Delta F} \qquad (2)$$

The thermal agitation voltage developed by a resistor is

$$E^2 = 4KTR\Delta F \qquad (3)$$

where R is the resistance, ΔF is the frequency band passed, T is the temperature in degrees Kelvin and K is Boltzmann's constant (1.39×10^{-23}).

If the impedance in the grid circuit is not a pure resistance, the resistive component is a function of the frequency and the voltage can be obtained from:

$$E^2 = 4KT \int_{F_1}^{F_2} R(f)\, dF \qquad (4)$$

These formulas apply only to wire-wound resistors or to carbon resistors in which no current is flowing.

There is always some capacitance across a resistor and this parallel combination forms a low-pass filter which affects the thermal agitation voltage e as follows:

$$e = 1.28 \times 10^{-10} \sqrt{RF_0 \left(\tan^{-1} \frac{F_2}{F_0} - \tan^{-1} \frac{F_1}{F_0} \right)} \qquad (5)$$

where $F_0 = 1/2\pi RC$ and F_2 and F_1 are the upper and the lower frequency limits, respectively, being

Omission of the grid leak in a conventional low-level amplifier, leaving only surface leakage paths between the grid and cathode, reduces the noise due to shot effect and thermal agitation. A cathode resistor of proper size gives further lowering of noise level

considered. It can be seen from Eq. (5) that the thermal agitation voltage output of an *RC* combination is independent of the value of *R*, because $F_1 = 0$ and $F_2 = F_0$, reducing e from a function of *R* and *C* to a function of *C* only.

If the noise voltage from an *RC* combination is applied to an amplifier, some of this voltage may be in a part of the frequency spectrum which is not passed by the amplifier. In this case the voltage passed by the amplifier would be a function of *R* as expressed in Eq. (5), where F_1 and F_2 would now be the frequency limits of the amplifier, and *R* and *C* would be the grid leak and the input capacitance in the amplifier circuit. If F_1 is very much less than the upper frequency limit of the amplifier, Eq. (5) reduces to:

$$e = 1.28 \times 10^{-10} \sqrt{\frac{1}{2\pi C} \cot^{-1} \frac{F_1}{F_2}} \qquad (6)$$

The form of Eq. (5) can be changed to show more clearly the relation between the thermal noise and the value of *R*.

$$e = 1.28 \times 10^{-10} \sqrt{\frac{1}{2\pi C} (\tan^{-1} 2\pi F_2 CR - \tan^{-1} 2\pi F_1 CR)} \qquad (5a)$$

$$\tan\left[\frac{2\pi Ce^2}{(1.28 \times 10^{-10})^2}\right] = \frac{2\pi C (F_2 - F_1) R}{1 + 4\pi^2 F_1 F_2 C^2 R^2} \qquad (5b)$$

Eq. 5(b) shows that the noise increases as the value of *R* increases from zero, reaches a maximum at some finite value of *R*, and decreases as the value of *R* is increased beyond this value. This equation shows that operation of a tube with an open grid would be less noisy than operation with a grid leak. In an amplifier circuit, to obtain minimum noise, the grid leak is sufficiently high if the thermal noise is less than the shot effect.

Another source of noise is the flow of leakage current between the cathode and the grid. This noise would be at a minimum when the cathode-to-grid voltage is at a minimum. Thus the tube would be quietest with a proper value of bias and it remains to be shown that the open grid tube automatically biases itself to that bias voltage.

To aid in determining the desirability of an open grid, a low noise level, wide-range amplifier was built. The first stage had a 6SJ7, triode-connected, with a gain of 11 db. The next two stages, using 6SJ7 tubes, had a gain of 68 db. The output stage, using a 6J5, was a cathode follower. The frequency response was down 6 db at 200 cy-

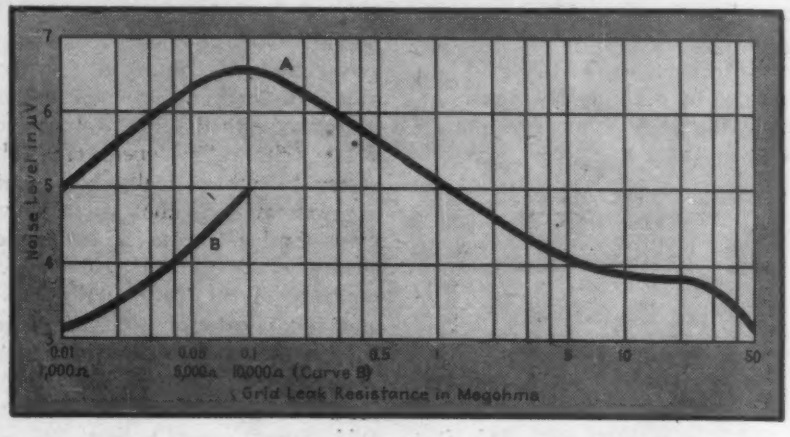


FIG. 2—Noise level vs. grid leak value for a triode-connected 6SJ7 tube. Curve B is for very low values of grid-cathode resistance

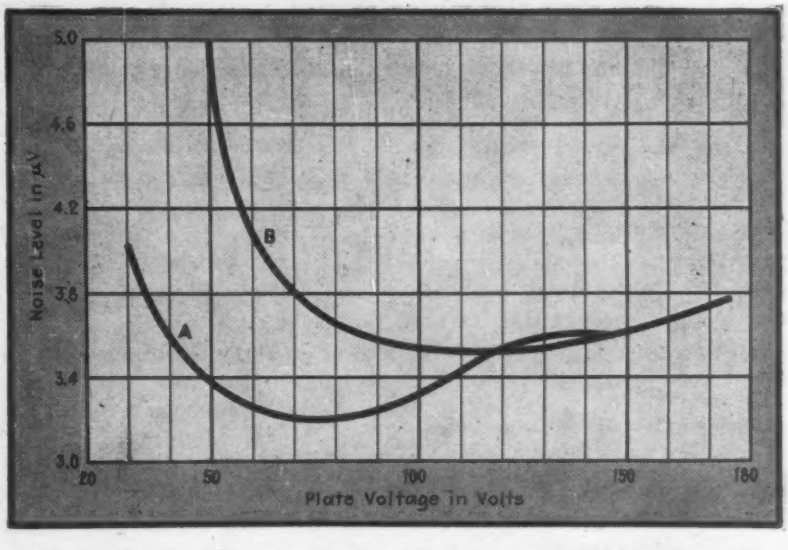


FIG. 3—Noise level vs. plate voltage for a triode-connected 6SJ7 tube with two different grid circuit arrangements. Curve A—40 μμf in grid circuit; curve B—40 μμf in parallel with 35 megohms in grid circuit

cles and at 200 kc. The entire amplifier was built in a copper box which gave excellent shielding. Because flicker noise is a low-frequency effect and not dependent upon the grid leak, a high-pass constant-K filter was placed at the output of the amplifier to suppress frequencies below about 650 cps and thus substantially eliminate the flicker effect.

Experiments With Open-Grid Tubes

The first tests were made with a cathode resistor alternately in and out of the first stage. A 40-$\mu\mu$f capacitor was used in the grid circuit to simulate the condition of an open-grid tube operating from a high-impedance crystal. For the next two measurements a 35-megohm resistor was put in parallel with the capacitor to give the condition of operation with a high-value grid leak. Finally, the grid was shorted to obtain the value of the tube noises. The noise at the grid was obtained by dividing the noise output by the gain. Typical results are given in Table 1.

TABLE 1. EFFECT OF CATHODE RESISTOR ON NOISE

Cathode Resistor	Grid Circuit Impedance	Noise at Grid (μv)
In	40 $\mu\mu$f	5.32
Out	40 $\mu\mu$f	4.26
In	40 $\mu\mu$f and 35 meg.	3.68
Out	40 $\mu\mu$f and 35 meg.	8.40
In	Short	3.00
Out	Short	3.66

These results show that the noise is less with an open grid than with a grid leak. In all three cases the noise is less with a cathode resistor than without one. This result is to be expected, for the cathode resistor voltage drop reduces the voltage between the cathode and the grid, reducing the leakage current and the noise resulting from it. The value of noise obtained with a grid leak and no cathode resistor is exceptionally high, probably because the zero bias allows a comparatively high value of grid current to flow through the carbon grid leak, greatly increasing the noise across the resistor.

Effect of Cathode Resistor Value

Noise measurements were taken with different sizes of cathode resistors. The test was made with 40 $\mu\mu$f in the grid circuit. The resulting curve of noise level vs. cathode voltage is not so important as the curve of noise level vs. cathode-grid voltage. Since this voltage cannot be measured directly because any voltmeter would upset the circuit conditions, it was necessary to obtain a calibration curve of plate potential vs. grid voltage without a cathode resistor.

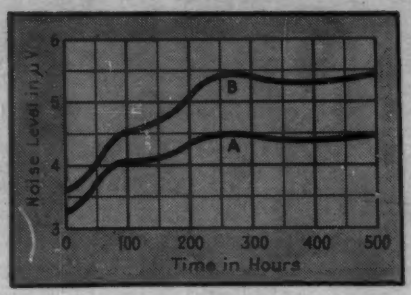


FIG. 4—Noise level vs. number of hours of continuous operation for a triode-connected 6SJ7 tube. Curve A—40 $\mu\mu$f in grid circuit; curve B—40 $\mu\mu$f in parallel with 35 meg in grid circuit

The curve of noise level vs. cathode-grid voltage is given in Fig. 1. Least noise is obtained for that value of cathode resistor which gives a cathode-grid voltage of −1.2 volts. The open-grid tube seems to automatically bias itself approximately to that value which gives the least noise. The effect of electron flow to the grid (which tends to make the grid negative) and the effects of emission from the grid and gas current to the grid (which tend to make the grid positive) balance each other to give the grid a small negative bias.

The foregoing test was repeated with a 35-megohm grid leak in addition to the 40-$\mu\mu$f capacitor. The minimum noise obtained was greater than the minimum noise without the grid leak.

Effect of Grid Leak Value

Figure 2 shows the relation between the noise level and the value of grid leak. These readings were taken with a 750-ohm cathode resistor. Except for a shorted or nearly shorted grid the best signal-to-noise ratio is obtained with an open grid. For the constants in this test, i.e., amplifier frequency response and input capacitance, the worst ratio is obtained for a grid leak around 100,000 ohms. For a different amplifier the worst ratio would occur at a different value of grid leak but the general shape of the curve would be the same. These results are in agreement with Eq. 5(b) and the discussion following it.

Effect of Plate Voltage

The relation between the plate voltage on a tube and the noise level at the grid is given in Fig. 3. Again there is less noise without a grid leak than with a grid leak, but in both cases the best signal-to-noise ratio is obtained for a plate voltage of about 90 volts.

It would be expected from Eq. (1) that the noise would continue to decrease as the plate voltage is increased because the g_m is increasing. However, the larger number of positive ions and secondary electrons present in the tube at higher plate voltages tends to make the tube slightly noisier.

Effect of Temperature and Time

In various measurements it was noticed that the noise changed as the temperature of the tube changed, the noise in a cold tube being greater than the noise in a warm tube. This effect is undoubtedly due to leakage paths, which change as the tube is heated and become saturated when the tube is hot. The change in the noise level is just as great with a grid leak as without one, and thus the addition of a grid leak does not reduce the noise due to the random leakage paths. An attempt was made to reduce this transient effect by boiling the tube and its socket in wax, but this did not help nor did it reduce the noise level.

A long-time test was performed on five 6SJ7 tubes by continuously drawing plate current through the tubes and measuring the noise level at certain time intervals. Typical results are given in Fig. 4. It can be seen that the tubes have a general tendency to become noiser with age, but that in all cases, the noise is greater with a grid leak than without a grid leak. These tests show that tubes operated without a grid leak do not tend to become any more erratic than tubes operated with a grid leak.

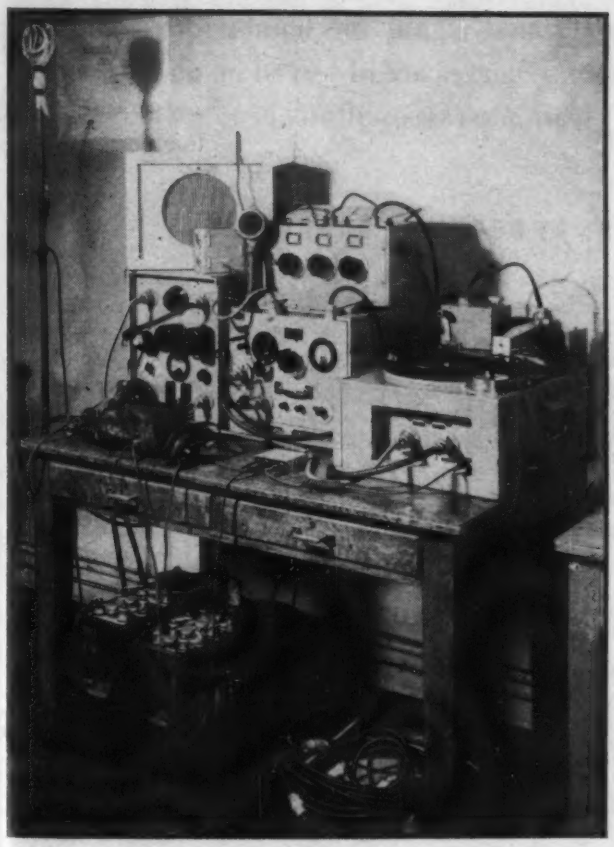
Conclusions

In the experiments performed, the noise level was always less without a grid leak than with one. In

(*Continued on page* 234)

Recording equipment developed by the British Broadcasting Corp. for use at the front is often housed in trucks of this type, which include living facilities, 200 yards of microphone cable, a shortwave receiver and a three-channel mixer

RECORDERS at WAR



RIGHT—Midget recorder developed by BBC weighs only 37 lb. Driven by a double-spring motor, it contains amplifier and batteries. Single knob turns amplifier on, starts turntable, and lowers piezo-electric cutter. Volume indication is by neon lamp. Disks are double-sided with three-minute playing time and 15 are carried. Fifteen seconds before the end of cut a warning light appears

LEFT—Closeup of 450-lb. recording equipment shows arrangement for use in a motor torpedo boat. Turntable at the right is powered by a 12-v d-c motor with friction drive. Speed-control rheostat works in conjunction with neon stroboscope run by a stable oscillator. High-sensitivity cutter-head has satisfactory response from 60 to 4500 cps. Pentodes are used in the first amplifier stages and in the output stage in push-pull while negative feedback keeps total harmonic content below one percent at normal recording level. Program-level meter operates from a diode rectifier and pentode amplifier. Motor-generator, driven by nickel-iron battery, provides plate voltages

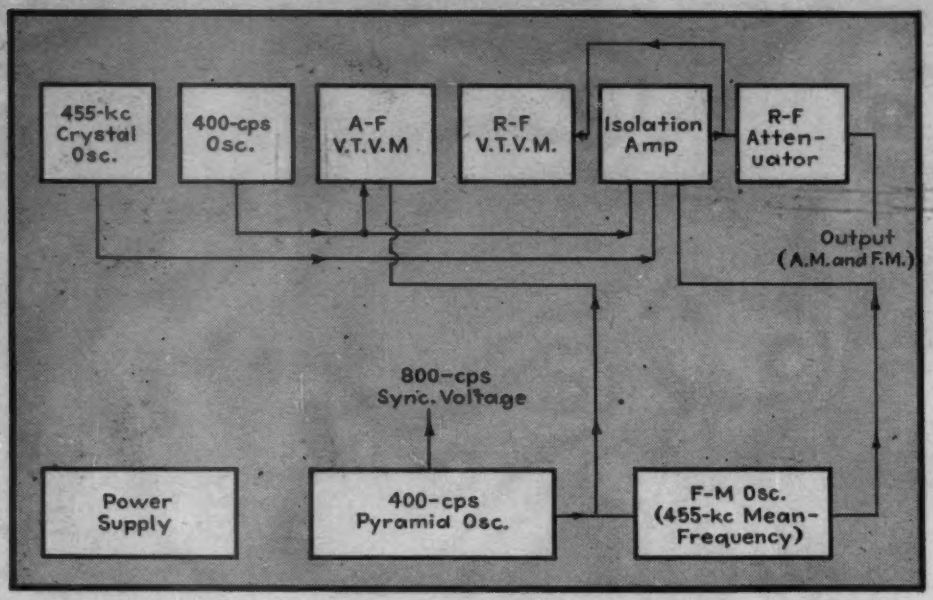


FIG. 1—Block diagram of the test unit, shown without switching. A complete schematic is given in Fig. 5

Visual Alignment of

Production test unit provides an amplitude-modulated signal for sensitivity measurements and a frequency-modulated signal for band-width adjustments. Response curves are observed on an external cathode-ray oscilloscope

By H. A. COOK and HAROLD MOSS

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ALIGNMENT of the wide-band i-f amplifiers in high-fidelity receivers on a production basis is a difficult operation. One common method involves the use of an amplitude-modulated signal generator and an output meter for sensitivity measurements, and a frequency-modulated signal generator in conjunction with a cathode-ray oscilloscope for band-width adjustments. Obviously, the adjustment and switching of several instruments introduces complications.

This paper describes a production test unit which greatly simplifies the job. It contains an a-m generator, an f-m generator, an isolation amplifier and an output attenuator common to both generators, an a-f vacuum-tube voltmeter and an r-f vacuum-tube voltmeter. It also provides synchronizing voltage for an external oscilloscope. A block diagram of the test unit, with switching omitted, is shown in Fig. 1.

A-M Signal Generator

The a-m signal generator consists of a 455-kc crystal-controlled 6SJ7 in a Colpitts circuit, driving a 6C5 cathode-follower type amplifier which provides low-impedance output. With a reasonably active crystal, about 400 cycles of frequency adjustment may be obtained by varying the tuned-circuit constants. Temperature control of the crystal is unnecessary.

The a-m generator is modulated in the grid circuit of the separator tube. The modulator, which operates at 400 cps, is of the *R-C* type shown in Fig. 2 and its frequency is given by the expression

$$f = 1/(2\pi\sqrt{C_1C_2R_1R_2})$$

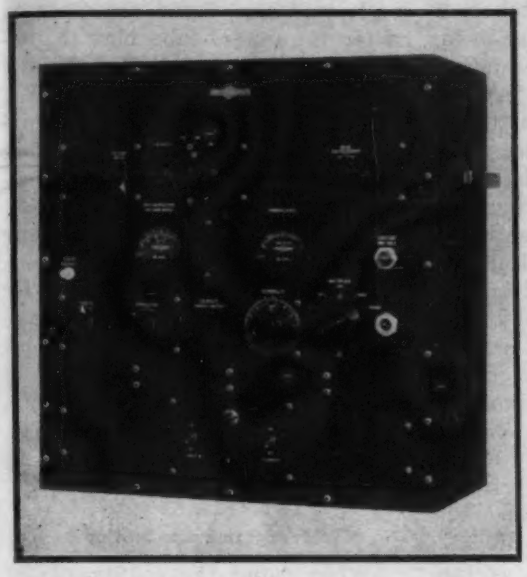
This circuit provides an excellent source of sinusoidal audio frequency.

Improved stability of oscillation results when a ballast resistor of some kind, rather than an ordinary resistor, is placed at R_3. A 3-watt 110-volt lamp seems satisfactory.

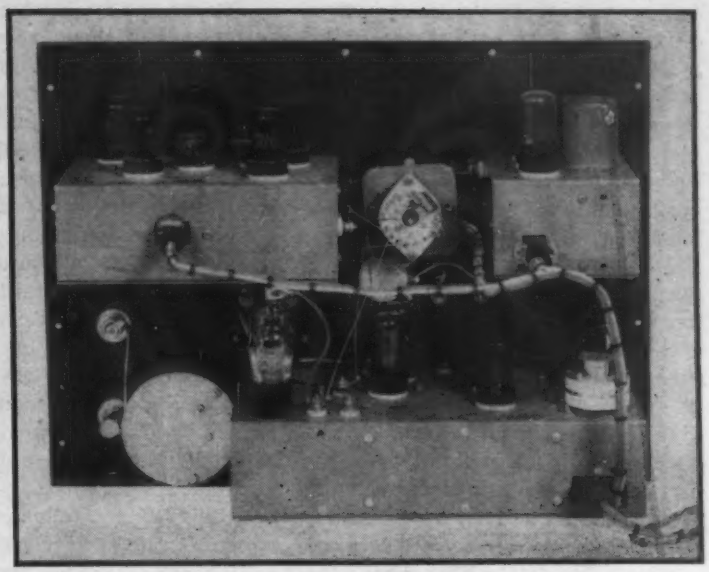
F-M Signal Generator

While the *R-C* oscillator circuit of Fig. 2 is ordinarily used at audio frequencies, it is equally adaptable to radio frequencies.[1]

From the expression for frequency of oscillation given above, it is apparent that a variation of R_1, R_2, C_1 or C_2 will result in a variation in frequency. By substituting the plate resistance of a vacuum tube for either R_1 or R_2 and varying



The production test unit. A cathode-ray oscilloscope is used externally



Back view of the test unit, with the bottom section (containing the power supply) removed

Wide-Band I-F Amplifiers

the grid voltage at an audio rate, frequency modulation will result. A logical choice indicated the selection of R_2 as the variable element, since it had one end at ground potential.

In order to obtain practical values for R_1, R_2, C_1 and C_2 at 455 kc, the cathode-follower circuit was used for R_2 in the actual circuit. Varying the grid voltage in the cathode-follower stage then varies the frequency of oscillation. Figure 3 indicates the variation in frequency obtained as the grid potential of the variable-resistance tube serving as R_2 is varied. As may be seen, frequency excursions of 80 kc are possible with a four-volt peak audio signal.

An ordinary resistor, rather than a ballast resistor, is used at R_3. A ballast resistor does not operate satisfactorily at R_3 at the higher frequencies, although an improvement in wave form results. At 455 kc, the ballast resistor swings constantly, seeking equilibrium, which shifts the mean-frequency several kilocycles. This objectional effect is not important at audio frequencies.

A 6SN7 connected as a multivibrator operating at 400 cps supplies about 50 volts to a 6SJ7 clipper circuit.[2] The output of the clipper circuit is a pyramid wave, extremely sharp at the corners and nearly straight sided. It proved wise to adjust the constants of the multivibrator until the resultant square-wave pulses were of equal lengths, as this affects the symmetry of the pyramid. A slight curvature still remaining on one pyramid slope is due to loading of the multivibrator on one side only; however, this is minor and of little consequence. About 4.9 volts peak is available at the output, the wave form of which is shown at Fig. 4.

Connection of the pyramid wave to the modulating grid of the resistor tube constituting R_2 causes frequency modulation linear with time; that is, the rate of change is constant across the entire excursion.

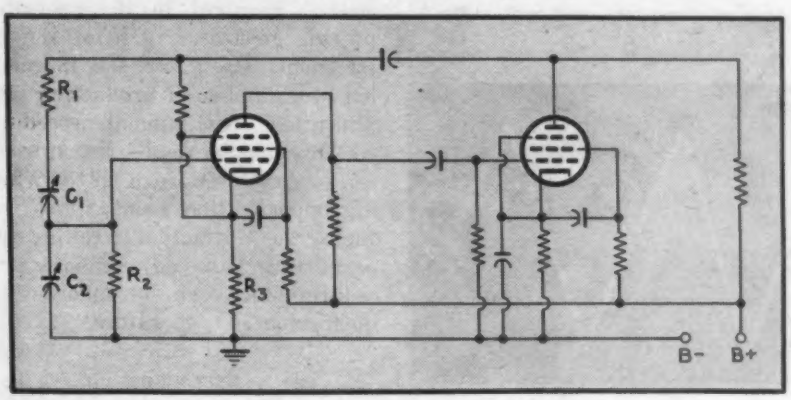


FIG. 2—Simplified schematic showing the type of *R-C* oscillator circuit used to obtain 400-cps modulation of the 455-kc amplitude-modulated signal generator. A similar R-C circuit is used as the frequency-modulated signal generator

Oscilloscope Synchronization

The necessary double frequency to properly synchronize the double-

humped image is obtained from a point common to both plates of the multivibrator, which supplies a pulse on each half of the square wave, serving as a frequency doubler. About 2 volts is available to drive a resonant amplifier at 800 cps, the output of which is an excellent sine wave.

It proved necessary to supply synchronizing pulses in this manner because of the tendency of the oscilloscope sweep to "pull" on every other cycle if the pulse is supplied at modulating frequency. This gives an erroneous pattern, as the uncontrolled cycle will not properly overlap, and leads to incorrect adjustment. In addition, the oscilloscopes available had interlocking controls. Also, when they were supplied with a square synchronizing pulse the sweep would trigger at times difficult to control, making it very hard to center the image.

The use of a sine wave, making it possible to adjust the triggering time of the sweep circuits along an even slope, plus the incorporation of a phase-shift network ahead of the sync output, makes it possible to obtain smooth adjustment of the position of the image. About 80 degrees phase shift is available at the grid of the sync output section of the 6SN7, using an R-C network with $R = X_c$. This, plus the apparent phase shifts possible by adjustment of the oscilloscope-sweep triggering level, permits positioning of the trace without the usual jockeying of controls. About 6 volts rms at 800 cycles is obtained from the sync output, reducing to about 4 at maximum phase shift.

An 800-cps amplifier incorporated in the test unit utilizes a toroid coil with a good Q (about 45 at 1000 cps), and an inductance of about 169 mh, those being the values available in toroids of small sizes.

The value of double-frequency sine-wave synchronization has been demonstrated in the ease with which oscilloscope positioning is obtained during production tests.

Other Circuit Details

The precision slide-wire attenuator common to both signal generators is directly calibrated in microvolts. Maximum f-m and a-m output values are greater than two volts, developed across 500 ohms.

The a-f and r-f vacuum-tube voltmeters are of the same type, being peak reading and calibrated in rms values. Some wave form error is caused by the pyramid, but this is of no consequence since these values are calibrated in terms of the f-m excursion. The latter was found on a band-width meter, but can be approximated for all practical purposes by the shift attained in variation of the resistance tube bias.

The incorporation of a sensitivity control in both vtvm circuits permits considerable tolerance in resistor values, always a difficult problem. Due to the highly degenerative circuit used, tubes are usually fully interchangeable. The two-volt scale is nearly linear.

The power supply unit is conventional in design. Voltage-regulator tubes were employed to aid in stabilizing the f-m oscillator, which proved somewhat critical of supply voltage.

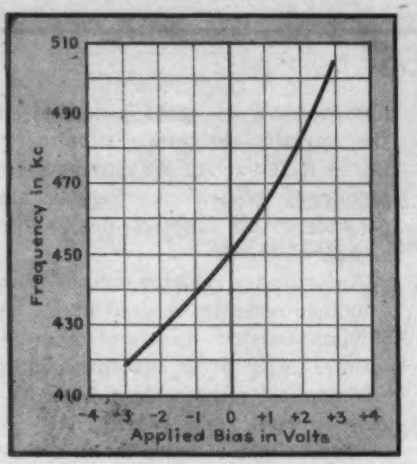


FIG. 3—Variation in f-m oscillator frequency around the 455-kc mean-frequency obtainable by changing the bias on a resistance-tube used as R_2 in Fig. 2

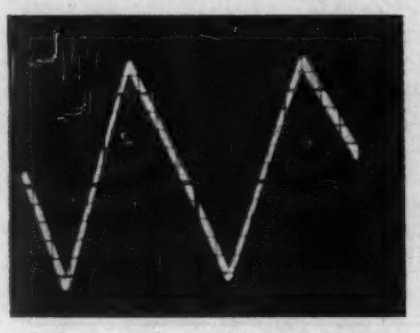


FIG. 4—Output wave form of the 400-cps pyramid oscillator used to modulate the f-m signal generator

It was also found necessary to filter the output-tube bias to prevent 120-cycle modulation. This is accomplished with a simple R-C circuit. The available bias is quite constant, staying within 5 percent in spite of a load variation of better than 2:1.

The complete circuit schematic for this test unit is shown in Fig. 5, with component values suitable for 455-k operation. Care must be taken to prevent interaction between circuits and the leakage of extraneous signals into the output. Adequate shielding and careful layout will tend to minimize all trouble of this nature.

Production Application

When using the equipment for production alignment of receivers a preliminary alignment is usually first made on amplitude modulation, adjusting the i-f amplifier to maximum output and taking a reading of overall sensitivity. At this point, sets showing insufficient gain are diverted to the repair lines.

The generator is then switched to f-m output and adjusted to 455 kc mean frequency. The sweep is adjusted to superimpose the traces. It is now possible to make the corrections in i-f tuning for symmetry and width of the "nose" of the trace. The wide excursion of frequency available permits examination of any stage with a simple adjustment of the band-width control.

The final check is made with a-m output as the above procedure reduces the overall sensitivity by a small amount. F-M alignment is not an end in itself, due to the many variables encountered.

A well-trained operator is, of course, required in the operation of this generator. Use of the instrument as a final check, however, led to a number of production simplifications in alignment procedure. As an example, an i-f transformer can be resistive-loaded on the winding opposite that being tuned, reducing the interaction in tuning and permitting an adjustment procedure which can be followed by inexperienced operators.

References

(1) Chang, C. K., F-M Resistance-Capacitance Oscillator, *Proc. IRE*, Jan. 1943.
(2) Mayer, H. F., Visual Alignment Generator, ELECTRONICS, April 1940.

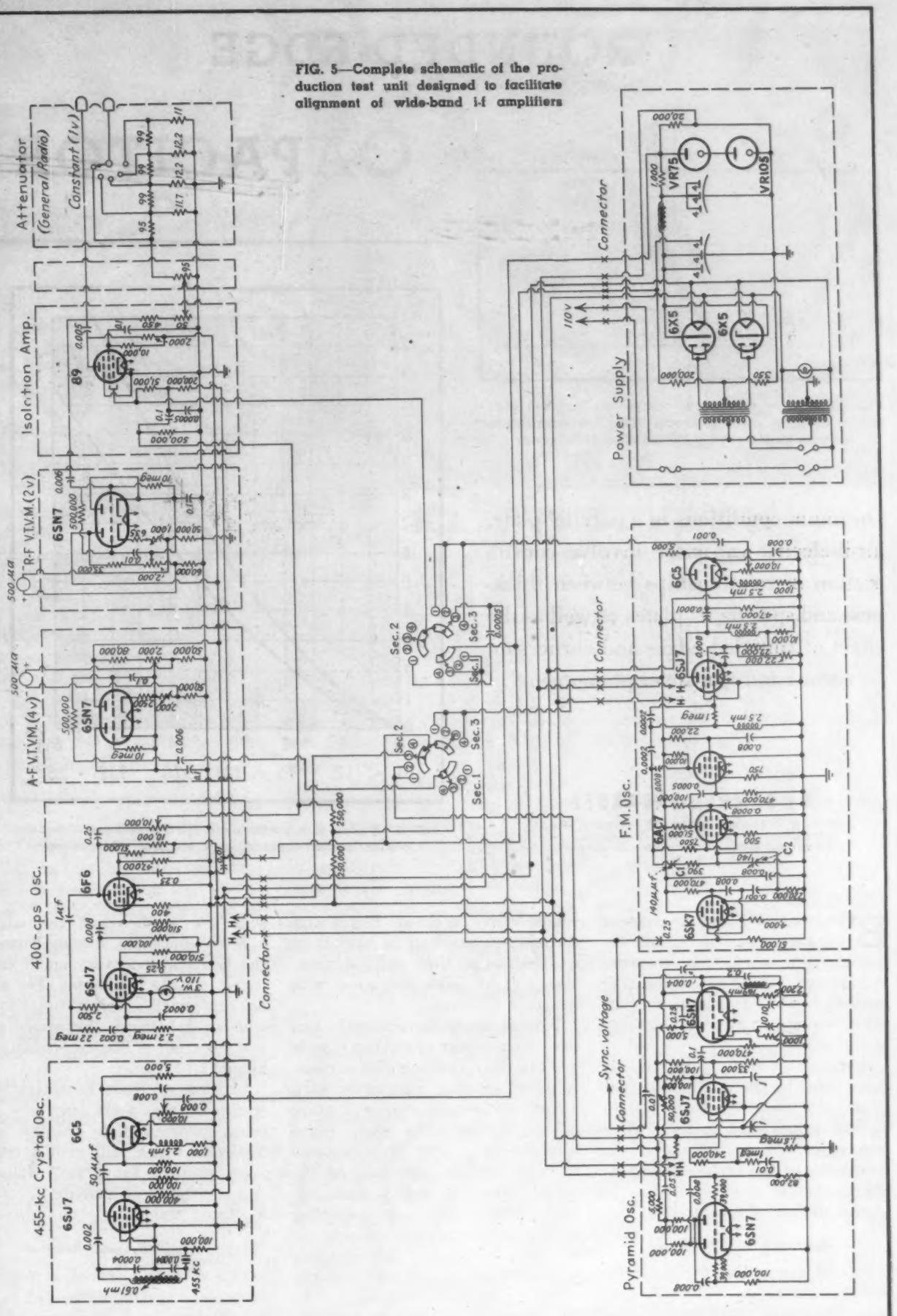


FIG. 5—Complete schematic of the production test unit designed to facilitate alignment of wide-band i-f amplifiers

ROUNDED-EDGE CAPACITOR

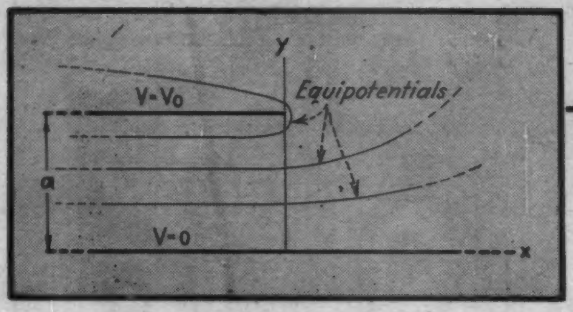


FIG. 1—Situation adjacent to one infinite and one semi-infinite capacitor plate in space. Note that equipotential contours tend toward a curved-edge plate, above

Optimum conditions in a parallel-plate, air-dielectric capacitor involve consideration of relationships between thickness and spacing of plates as well as the effect of rounded edges and corners on corona and sparkover phenomena

By SAMUEL SABAROFF

WCAU Broadcasting Co., Philadelphia, Pa., Consultant to Barker and Williamson, for whom this material was originally prepared.

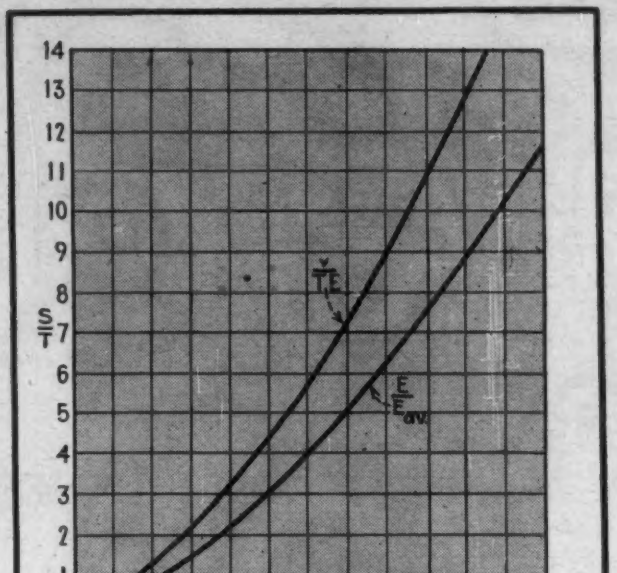


FIG. 2—Values of capacitor-plate spacing-thickness ratio are plotted against potential and gradient relationships

BETWEEN two oppositely charged parallel plates of infinite extent the field is said to be uniform. It is known, however, that the field between two finite plates is *not* uniform, tending to greater gradients at the edges.

Stress at a point in a dielectric is determined by the gradient at that point and stresses above certain critical values lead to the formation of corona and sparkover. A knowledge of the factors determining maximum gradient assists in proper design of a capacitor.

Approach is Analytical

In this discussion, the dielectric will be taken as air. Plate thickness is assumed to be small, compared to any other linear dimension, except where otherwise noted. Plates with corners are assumed to have them rounded so that their radii of curvature will be large compared with the plate thickness.

It is an easily demonstrable fact that the gradient at a sharp edge is greater than at a rounded surface. Application of a sufficiently high voltage to a conductor will make corona stream from sharp edges while there is very little evidence of it on the flat surfaces. At the outset, then, it would seem advantageous to construct a capacitor with edges having a maximum radius of curvature. Disregarding the possibility of curling the edges over to increase curvature, the plates should be as thick as possible up to a certain point. This lessens the gradient at the edges.

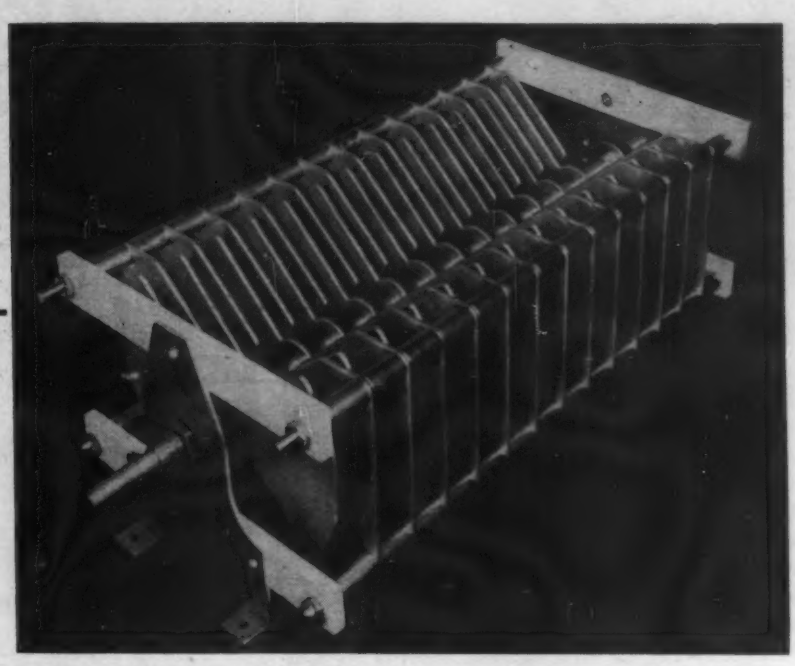
Now suppose the spacing between the two plates is very small compared to plate thickness. For sufficiently small spacing, breakdown will occur between the plates and the edge effect becomes relatively minor.

In view of these considerations it appears that there may be a relation between plate spacing and thickness which will give a minimum gradient for a fixed voltage and a given plate spacing. This is the basic design problem.

Spacing-Thickness Relation

This may be pictured as follows with plate spacing identified as S and thickness as T. For large values of S/T the radius of the plate edge

PLATES



Rounded edges are a corona and sparkover-resistant feature of this Barker and Williamson capacitor. Type is similar to those discussed in the text

is small and a high gradient exists there. As plate thickness is increased—keeping plate center-to-center spacing and applied voltage constant—the radius of edge curvature is increased. This decreases the edge gradient. Inside the capacitor however, the gradient increases because of the reduced spacing. The best value of S/T can be located at the crossover point between these two opposing effects. At this point the maximum gradient that can occur becomes a minimum. Such critical values have been calculated and observed for other electrode shapes.[1]

It has been suggested by Ekstrand[2] that the best value of S/T may be between the values of 2 and 3. This investigation seems to corroborate his figures by fixing the optimum S/T at 2.77.

What Constitutes Breakdown?

Let us now consider some factors having to do with capacitor breakdown. It has become somewhat of a habit to consider breakdown as coincidental with sparkover. Actually breakdown has occurred at the first sign of corona, and corona may become evident at a considerably lower voltage than sparkover.

When a conductor is raised beyond a certain critical potential, the air adjacent to it becomes ionized, forming corona. The ionized air, being itself a conductor, can be considered to increase the size of the original conductor. If this effect is accompanied by an increase of gradient, the condition becomes unstable and sparkover occurs. If there is a decrease in gradient, the condition is stable and corona remains as such.

Application of this concept to our capacitor is almost obvious. Suppose that S/T is greater than the critical value. Now, as we apply a gradually increasing voltage, corona will commence. If we consider the corona as part of the plate, then in effect the plate thickness has been increased, thus reducing the value of S/T. Sparkover should then take place when the value of S/T is less than the optimum.

If we start applying voltage when S/T is less than the best value, then the transition from corona to sparkover is almost instantaneous since an increase in plate thickness will increase the gradient. Of course, there are irregularities in the practical manifestation of this principle. One reason is that corona will not form uniformly on the plates, being most evident where the gradient is maximum.

It has been found that in the case of wires, spheres, and concentric cylinders[3], corona appears for a constant gradient at a distance proportional to $\sqrt{r}$ from the surface, where r is the radius. It may therefore be expected that experiment will show the existence of a similar factor in the formation of corona at the edges of a capacitor.

The microcosmic picture of air breakdown is complex and even of a somewhat metaphysical nature[4] but breakdown characteristics have, in general, been determined by experiment.

This discussion concerns, in the main, a calculation for the best value of S/T. Note that the derivations and approximations are guided by existing physical conditions. Results must inevitably be tested by experiment and qualified where necessary.

Basic Assumptions

Assume that the plates are semi-infinite in extent and that the radius of curvature of an edge is equal to half the plate thickness. Because of symmetry, thus applying the theory of images, it only will be necessary to consider the field between one semi-infinite plate and an infinite plate. This latter is placed midway between the semi-infinite plates and has a potential equal to half their sum.

First, however, consider a pair of plates that are of extreme thinness. The solution for this case is well known.[5] An approximate plot of the equipotentials is shown in Fig. 1, in which it is assumed that the semi-infinite plate has a potential of V_0 volts with respect to the infinite plate and is spaced a inches from it.

Notice particularly the trend in the shape of the equipotentials as they approach the semi-infinite plate. Any equipotential can be replaced by a conductor (of the same

TABLE I. PLATE-DIMENSION RATIOS AND VOLTAGES OF CAPACITORS AT VARIOUS FREQUENCIES

T in.	S in.	S/T	Sparkover kv			Max. gradient (calculated) kv/in.		
			60 cps	700 kc	1500 kc	60 cps	700 kc	1500 kc
0.128	0.218	1.705	14.0	13.5	13.7	89.1	85.8	87.1
0.04	0.192	4.8	8.4	7.59	6.82	80.2	72.5	65.1
0.064	0.719	11.24	24.0	14.28	11.7	82.0	48.8	40.0

shape and charged to the same potential) without disturbing the external field in any way. Thus, if the equipotentials are replaced by equivalent plates, they will tend to an ordinary thin plate with rounded edges as the potential of the semi-infinite plate is approached. The procedure will now be to match, as far as possible, an actual plate to one of these equipotentials and thus obtain an expression for the maximum gradient at its edge. A somewhat arbitrary extension will then be made to indicate the maximum gradient on a plate of any thickness.

Potential around an infinitely thin plate, semi-infinite in extent, can be expressed in the following parametric form

$$\left.\begin{aligned} x &= \frac{a}{\pi}\left[1+e^{-\pi U/V_0}\cos(\pi V/V_0)-\pi U/V_0\right] \\ y &= \frac{a}{\pi}\left[e^{-\pi U/V_0}\sin(\pi V/V_0)-\pi V/V_0\right] \end{aligned}\right\} \quad (1)$$

where V is potential at any point having the coordinates xy. U is the force or stream function.

In complex form Eq. (1) is

$$Z = \frac{a}{\pi}\left(1+e^{j\pi W/V_0}+j\pi W/V_0\right) \quad (2)$$

where $Z = x + jy$, $W = V + jU$, and $j = \sqrt{-1}$.

Finding the Gradient

At any point the gradient is found by

$$E = \left|\frac{dw}{dz}\right| = \frac{V_0/a}{\sqrt{1+e^{-2\pi U/V_0}+2e^{-\pi U/V_0}\cos(\pi V/V_0)}} \quad (3)$$

where E is gradient in volts per inch.

Along an equipotential, the gradient will depend entirely on concentration of the lines of force. In order to find the point of maximum gradient for any potential, it will be necessary to maximize E partially with respect to force function U. Thus $\delta E/\delta U = 0$ when

$$e^{-\pi U/V_0} = \cos\left[\pi(V_0 - V)/V_0\right] \quad (4)$$

Substituting Eq. (4) in (1) and (3)

$$\left.\begin{aligned} x_m &= \frac{a}{\pi}\left\{\sin^2[\pi(V_0-V)/V_0] + \log\cos[\pi(V_0-V)/V_0]\right\} \\ y_m &= \frac{a}{\pi}\left\{\pi V/V_0 + \sin[\pi(V_0-V)/V_0]\cos[\pi(V_0-V)/V_0]\right\} \end{aligned}\right\} \quad (5)$$

and

$$E_m = \frac{V_0/a}{\sin[\pi(V_0-V)/V_0]} \quad (6)$$

As V approaches V_0, Eq. (5) and (6) become

$$\left.\begin{aligned} x_m &= \frac{a\pi(V_0-V)^2}{2V_0^2} \\ y_m &= a \end{aligned}\right\} \quad (7)$$

and

$$E_m = \frac{V_0^2}{a\pi(V_0-V)} \quad (8)$$

Selecting the Curvature

At this point it becomes necessary to determine the manner in which an actual plate should be matched to an equipotential. A reasonable condition is that the radius of curvature of the actual plate and the radius of curvature of the equipotential at the point of maximum gradient be made equal.

For the radius of curvature the formula is

$$R = \left[1+\left(\frac{dy}{dx}\right)^2\right]^{3/2}\left(\frac{d^2y}{dx^2}\right)^{-1} \quad (9)$$

At any point on an equipotential the radius of curvature, as found from Eq. (1) and (9), is

$$R = \frac{a\left[1+2e^{-\pi U/V_0}\cos(\pi V/V_0)+e^{-2\pi U/V_0}\right]^{3/2}}{\pi e^{-\pi U/V_0}\sin(\pi V/V_0)} \quad (10)$$

On any equipotential, at the point of maximum gradient, the radius of curvature is found by substituting Eq. (4) in (10), thus

$$R_m = \frac{a\sin^2[\pi(V_0-V)/V_0]}{\pi\cos[\pi(V_0-V)/V_0]} \quad (11)$$

As V approaches V_0, the radius of curvature becomes

$$R_m = a\pi(V_0-V)^2/V_0^2 \quad (12)$$

Let S equal the actual plate spacing and T equal the plate thickness. An approximate match can be assumed when $(y_m - R_m)$ is identified with $S/2$ and R_m is assumed equal to $T/2$. It is not necessary to consider x_m and it is now ignored. V is made equal to $v/2$ where v is the actual potential between the plates. When a and V_0 are eliminated from Eq. (7), (8) and (12),

$$S = \frac{v}{E}\left(\frac{v}{\pi ET}+\frac{2}{\pi}\right) + \frac{T(\pi-1)}{\pi} \quad (13)$$

where the subscript has been omitted from E_m.

Since T is assumed small with respect to S, the right-hand term can be omitted in Eq. (13), resulting finally in

$$S = \frac{v}{E}\left(\frac{v}{\pi ET}+\frac{2}{\pi}\right) \quad (14)$$

Up to this point a small value of T has been assumed with respect to S. Now disregard the derivation and consider Eq. (14) alone. If we allow the plate thickness to approach infinity in Eq. (14), it becomes

$$S = \frac{2}{\pi}\frac{v}{E} \quad (15)$$

Compare this with the relation

$$S = \frac{v}{E} \quad (16)$$

which holds for two plates in which the edge effect is negligible. This is equivalent to the condition when T equals infinity.

Condition Generalized

Similarity between Eq. (15) and (16) suggests the possibility of Eq. (14) being adjusted so that it would hold for T large as well as small. This can be done approximately by replacing the constant $2/\pi$ in Eq. (14) by unity, thus

$$S = \frac{v}{E}\left(\frac{v}{\pi ET}+1\right) \quad (17)$$

Eq. (17) is admittedly approximate. Assuming for the moment that its accuracy has been established, let us examine it for the presence of a best value for S/T. This best value is, of course, the

(*Continued on page 268*)

CATHODE FOLLOWER Calculations

Equations relating cathode follower output impedance to the value of the cathode resistor, the plate load resistance of the cathode follower tube, and the transconductance of the tube

By HUMBERT P. PACINI

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IN SOLVING for the output impedance of a cathode follower such as the one shown in Fig. 1(a) it is most convenient to set up the required circuit equations by assuming the cathode of the tube driven by a generator of voltage E_1 and internal resistance R_1. Fig. 1(b) shows the addition of this generator and Fig. 1(c) is the resulting equivalent circuit.

The general equations for a two-loop network are*

$$Z_{11}I_1 + Z_{12}I_2 = E_1 \quad (1)$$

$$Z_{12}I_1 + Z_{22}I_2 = E_2 \quad (2)$$

where Z_{11} is the total impedance in loop 1, Z_{22} is the total impedance in loop 2, Z_{12} is the mutual impedance between loops 1 and 2, and E_1 and E_2 are the generator voltages in loops 1 and 2 respectively.

According to Fig. 1(c) the equivalent voltage acting in the grid circuit, or the rise in voltage from cathode to grid, is $(I_2 - I_1)\,R_2$, and $-\mu(I_2 - I_1)\,R_2$ is the voltage acting in the plate circuit in the direction shown if it is taken as voltage driving I_2 clockwise. Upon substitution of these values in Eq. (1) and (2) there results

$$(R_1 + R_2)\,I_1 - R_2I_2 = E_1 \quad (3)$$

$$-R_2I_1 + (R_2 + R_p)\,I_2 = -\mu(I_2 - I_1)\,R_2 \quad (4)$$

Solving these two simultaneous equation yields for the driving point impedance

$$Z_1 = R_1 + R_2 - \frac{R_2^2\,(1+\mu)}{R_p + (1+\mu)\,R_2} \quad (5)$$

from which it is obvious that the impedance looking into the cathode; that is, the output impedance of the cathode follower, is

$$Z_1 - R_1 = R_2 - \frac{R_2^2\,(1+\mu)}{R_p + (1+\mu)\,R_2} = Z_{out} \quad (7)$$

Since μ is much larger than 1, especially in high-gain triodes and pentodes, Eq. (7) may be converted to

$$Z_{out} = R_2 - \frac{R_2^2}{(R_p/\mu) + R_2} = R_2 - \frac{R_2^2}{(1/g_m) + R_2} \quad (8)$$

This impedance is made up of the cathode resistance and the internal impedance of the cathode in parallel; and if Z_c represents the latter, Eq. (8) can be written

$$Z_{out} = \frac{Z_cR_2}{Z_c + R_2} \quad (9)$$

After transformation and substitution of Eq. (8) for Z_{out}

$$Z_c = [(1 + g_mR_2)/g_m] - R_2 = 1/g_m \quad (10)$$

If the cathode follower tube had been used with a plate load, either to limit the plate current or to provide a push-pull voltage, the equation for the internal impedance of the cathode follower would be

$$Z_c = (1/g_m) + (Z_L/\mu) \quad (11)$$

where Z_L is the plate load.

The internal impedance of a cathode follower is given by Eq. (10) for the case of no plate load, or by Eq. (11) if there is plate load. It is seen from Eq. (9) that the effect of the internal impedance of the cathode follower tube is to add an impedance Z_c, in parallel with the cathode load impedance.

* Everitt, W. L., "Communication Engineering", McGraw-Hill Book Co., p. 217-229.

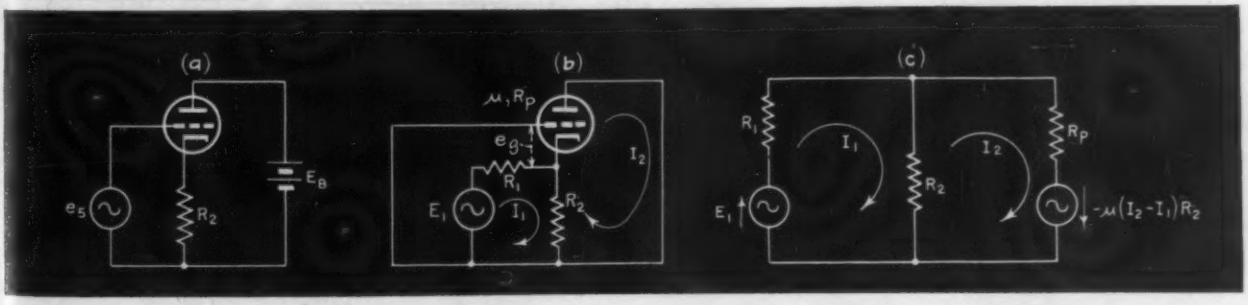

FIG. 1—(a) The actual circuit in which the impedance across R_2 is sought. In (b) a fictitious generator, E_1, of internal impedance R_1, is introduced. The equivalent circuit from which the derivation begins is shown at (c)

Circuit Response to NON-SINUSOIDAL

Short-cut method of determining the current response either graphically or analytically in circuits energized by square, saw-tooth, repeated exponential and similar waves, by decomposing into components starting at different instants, then adding responses

FOURIER'S analysis[1] is a general method for evaluating the circuit response to non-sinusoidal periodic waves. But it is not always the most convenient method for evaluating the transient response, especially to those non-sinusoidal periodic waves which are discontinuous in the wave itself or its derivative with respect to time. The actual solution of a problem by means of this method is sometimes tedious and time-consuming.

Another method, possibly first used by Poisson and later by Duhamel[2] and based on the superposition of step functions, decomposes any kind of waves, periodic or not, into so-called Heaviside unit functions[3] which start at different instants. This method has been used more extensively in treating non-periodic waves. In fact, it is a very powerful tool for evaluating the circuit response to some types of commonly encountered non-sinusoidal waves which are discontinuous in the wave itself or its derivative with respect to time, such as square waves, saw-tooth waves, trapezoidal waves, repeated exponential waves and output voltage waves of controlled rectifiers.

Owing to the geometry of the non-sinusoidal wave, an easier solution can often be obtained; instead of being decomposed into Heaviside unit functions, the wave can be decomposed into waves of other types which have the same wave form but start at different instants. This short-cut method (based on an extension of "superposition of step function," generally known as Duhamel's integral), permits determining the transient response easily by either analytical or graphical methods.

Decomposition of Square Waves

Square waves are used in the communications field for testing the frequency response of electric circuits[4]. A symmetrical square wave having an amplitude A and a period of $2t_1$ can be decomposed into a number of different constant-ampli-

* Based on a paper presented before the Chinese Institute of Engineers, American Section, in New York City July 2, 1944.

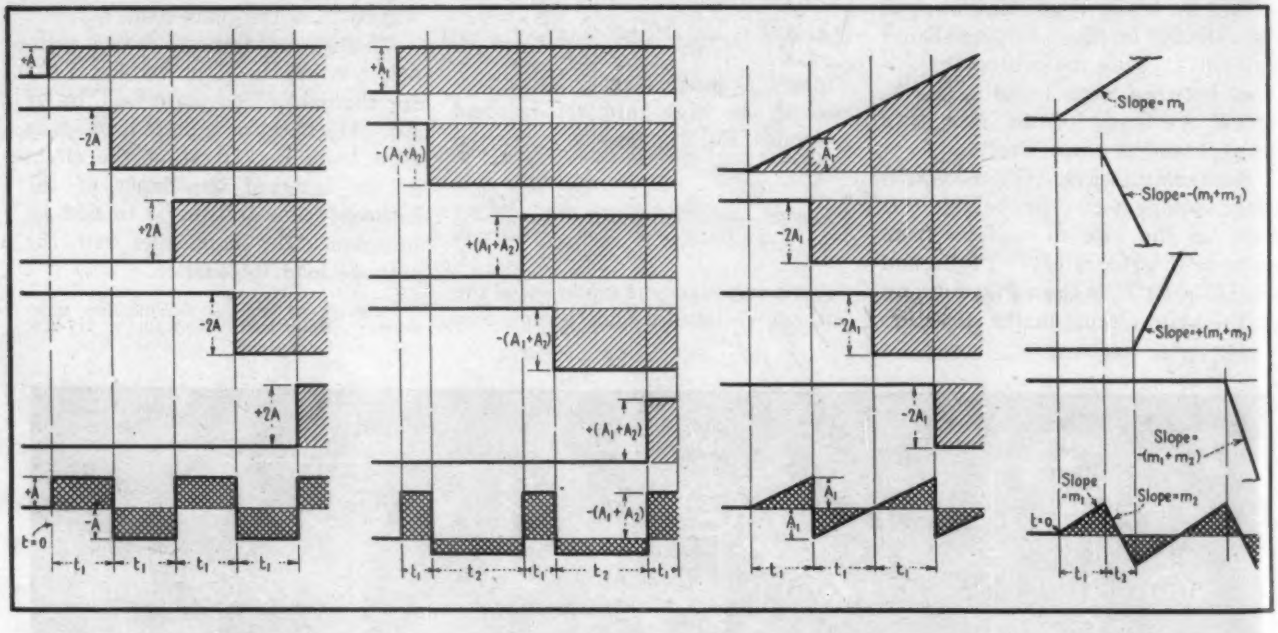

FIG. 1—Decomposition of symmetrical square waves shown at bottom with double shading

FIG. 2—Decomposition of unsymmetrical square wave into components shown above

FIG. 3—Decomposition of ideal saw-tooth wave into two types of components

FIG. 4—Decomposition of saw-tooth wave into rising and falling components

WAVE FORMS

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tude components starting at different time intervals, as shown graphically in Fig. 1. The first component starts at $t = 0$ and has an amplitude of $+ A$. The second starts t_1 later and has an amplitude of $-2A$. At interval t_1 after this, the third component starts with an amplitude of $+ 2A$. Thereafter, components of $-2A$ and $+2A$ in amplitude start alternately at successive intervals of t_1.

The decomposition of an unsymmetrical square wave, having unequal positive and negative amplitudes of A_1 and A_2 respectively, is shown in Fig. 2. The duration of A_1 is t_1, and that of A_2 is t_2.

Saw-Tooth and Trapezoidal Waves

Saw-tooth waves can also be used to test frequency response of electrical circuits. In some respects, these waves are superior to square waves, as suggested by Waidelich[5]. An ideal saw-tooth wave, having a slope A_1/t_1 and a period of $2t_1$, can be decomposed into a linearly rising voltage having a slope of A_1/t_1 and starting to occur at $t = 0$, plus constant driving forces of $-2A_1$ starting to occur at succeeding intervals of t_1 as shown in Fig. 3.

The saw-tooth waves of Fig. 3 can hardly be produced by practical means, since it takes some time for the saw-tooth wave to fly back to its original position. Figure 4 shows more practical saw-tooth waves which can be produced by some electronic circuits[6]. These waves can be decomposed into: A linearly rising wave of slope m, starting at $t = 0$; a linearly rising wave of slope $-(m_1 + m_2)$ starting t_1 later; a wave of slope $+(m_1 + m_2)$ starting at $t_1 + t_2$; a wave of slope $-(m_1 + m_2)$ starting at $2t_1 + t_2$, etc. (The linearly rising waves in Fig. 4 should continue to rise, but in order to save space they are not shown beyond the broken lines.)

Figure 5 shows the decomposition of trapezoidal waves. The procedure is more or less similar to that for saw-tooth waves.

Output Voltage Waves of Gaseous Rectifiers

When gaseous-discharge type rectifiers, such as thyratrons and ignitrons, supply an inductive load with continuous conduction of current, the geometry of the output voltage wave depends on the number of phases of the rectifier circuit and the angle of phase retard.[9]

Figure 6 shows the decomposition of the output voltage wave of a bi-phase uncontrolled rectifier circuit having no phase retard. It can be decomposed into a continuous sine wave having a peak value A_1, starting in a positive direction at $t = 0$, followed by a series of sine waves each having a peak value of $2A_1$, and starting in a positive direction every half-cycle later.

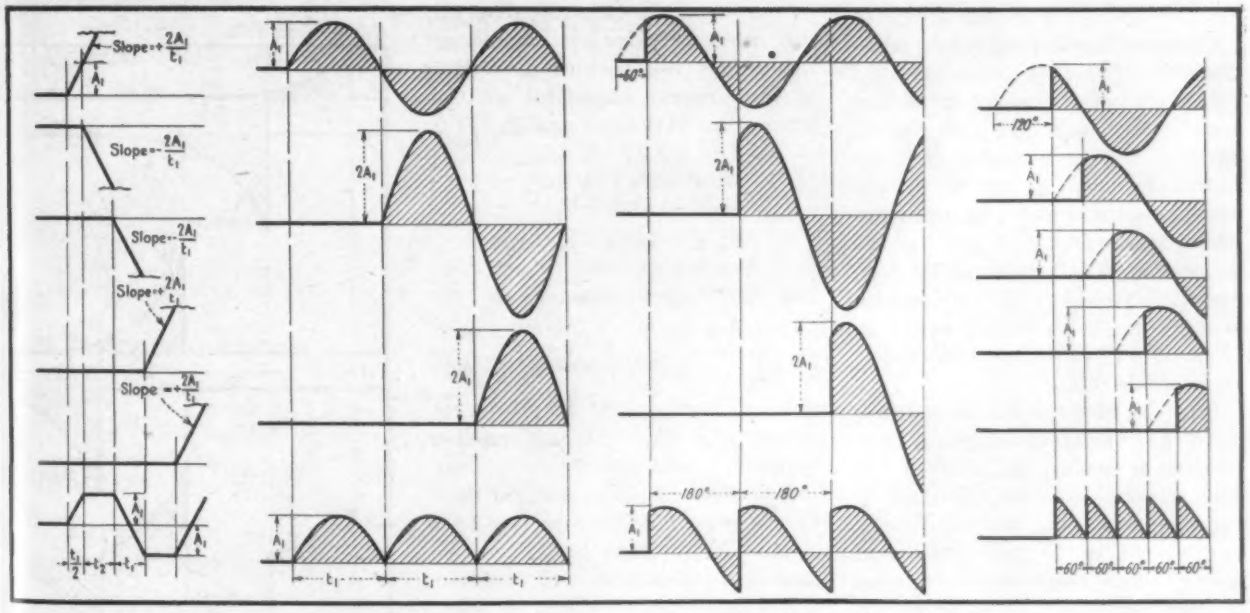

FIG. 5—Decomposition of trapezoidal waves. Components are cut off here to conserve space

FIG. 6—Decomposition of output voltage of bi-phase uncontrolled rectifier: no phase retard

FIG. 7—Decomposition of output voltage of bi-phase rectifier, phase retarded 60 degrees

FIG. 8—Decomposition of output voltage of six-phase rectifier, phase retarded 60 degrees

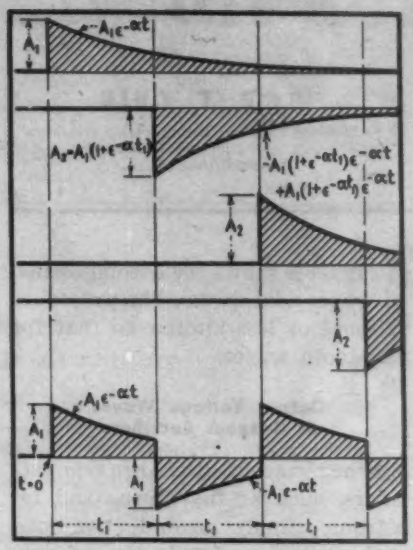

FIG. 9—Decomposition of repeated exponential waves

Figure 7 shows the decomposition of the output voltage wave of a bi-phase rectifier with a phase retard of 60 electrical degrees. It is evident that the decomposition is similar to that shown in Fig. 6 except that each sine wave starts with a magnitude corresponding to the value A_1 sin 60° instead of zero.

Figure 8 shows the decomposition of the output voltage wave of a 6-phase rectifier. The continuous sine waves are spaced at 60° and all the sine waves have the same peak value A_1.

Repeated Exponential Waves

Repeated exponential waves sometimes occur in television circuits.* The period of the waves is $2t_1$ and each wave has the expression $A_1\ \epsilon^{-\alpha t}$. Figure 9 shows that repeated exponential waves can be decomposed into a exponential wave which starts at $t = 0$ and has the expression $A_1\ \epsilon^{-\alpha t}$, followed by component waves having the expressions $-A_1\ (1 + \epsilon^{-\alpha t_1})\ \epsilon^{-\alpha t}$ and $+A_1\ (1 + \epsilon^{-\alpha t_1})\ \epsilon^{-\alpha t}$, occurring alternately at intervals of t_1.

Once a non-sinusoidal periodic wave has been decomposed into component waves, the over-all circuit response can be obtained by superimposing the individual circuit responses on the component waves. These responses are similar in their wave form but start at different instants. Two examples, one for a square-wave voltage applied to R and C in series and the other for the output current of a bi-phase controlled rectifier supplying an inductive load, will be used to show the procedure used in both the analytical and graphical versions of this short-cut method of determining circuit response.

Circuit Response to Square Waves

Suppose it is required to find the transient response of a circuit to a symmetrical square-wave voltage having a magnitude A and a period $2t_1$. This involves finding the response during the existence of the nth square wave after the square-wave voltage is applied.

Analytical Solution

Taking the analytical solution first, assume that time is zero at the beginning of the $(n + 1)$th square wave, n being an even number. The component waves are

Component Wave	Magnitude	Instant at Which Wave Starts
$n+1$	$+2A$	0
n	$-2A$	$-t_1$
$n-1$	$+2A$	$-2t_1$
$n-2$	$-2A$	$-3t_1$
.....	.....	.....
3	$+2A$	$-(n-2)t_1$
2	$-2A$	$-(n-1)t_1$
1	$+A$	$-nt_1$

Let i_{n+1}, i_n, ..., i_2, i_1 be the current responses to the $(n + 1)$th, nth, ..., 2nd and 1st component waves respectively. Now, since the response of the circuit is a function of time [written $f\ (t)$, with its significance depending on the particular combination of circuit elements in the circuit], the individual circuit responses to the component waves may be specified as follows in the general analytical solution where time is defined as $t_1 \geqq t \geqq 0$:

$$\begin{aligned} i_{n+1} &= 2A\ f(t) \\ i_n &= -2A\ f(t+t_1) \\ i_{n-1} &= 2A\ f(t+2t_1) \\ &\cdots\cdots\cdots\cdots \\ i_2 &= -2A\ f[t+(n-1)t_1] \\ i_1 &= A\ f(t+nt_1) \end{aligned} \qquad (1)$$

The total current response is

$$\begin{aligned} i &= i_1 + i_2 + i_3 + \ldots\ldots\ldots + i_n + i_{n+1} \\ &= 2A\sum_1^n (-1)^{s-1} f(t+st_1) - Af(t+nt_1) \end{aligned}$$

$$t_1 \geqq t \geqq 0 \qquad (2)^*$$

where s is any integral number between 1 and n.

Equation (2) is a general solution of the circuit response to a square wave from its known response to a Heaviside unit function. The steady-state solution can be obtained by making n approach infinity.

* Equation (2) is also true when n is odd.

As an example of the analytical solution, suppose the circuit is made of a resistance R and a capacitance C in series. The circuit response to a Heaviside unit function $f(t)$ will be $(1/R)\ \epsilon^{-t/CR}$, and the total current response will be

$$i = \frac{2A}{R}\epsilon^{-t/CR}\left[\sum_1^n (-1)^{s-1}\epsilon^{-st/CR}\right] - \frac{A}{R}\epsilon^{-(t+nt_1)/CR} \qquad t_1 \geqq t \geqq 0 \qquad (3)$$

The expression in brackets is a familiar geometric series. When its sum is substituted in Eq. (3), the total current response becomes

$$i = \frac{2A}{R}\epsilon^{-t/CR}\left[\frac{1-\epsilon^{-(n+1)\,t_1/CR}}{1+\epsilon^{-t_1/CR}}\right] - \frac{A}{R}\epsilon^{-(t+nt_1)/CR} \qquad t_1 \geqq t \leqq 0 \qquad (4)$$

The steady-state solution can be obtained by letting n approach ∞:

$$i = \frac{2A}{R}\epsilon^{-t/CR}\left[\frac{1}{1+\epsilon^{-t_1/CR}}\right] \qquad t_1 \geqq t \geqq 0 \qquad (5)$$

The graphical solution for the current response during the first four square waves is summarized in Fig. 10. It is performed by plotting the circuit responses to component waves which have a magnitude of A for the first component and $-2A$ $+2A$ and alternatively for the successive components, spaced at a time interval of t_1. Superimposing all the responses gives the resultant current response, shown at the bottom in Fig. 10. The graphical method is

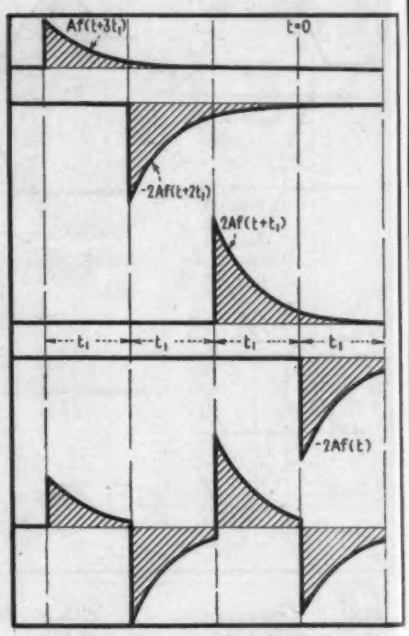

FIG. 10 — Current response where square-wave voltage is applied to R and C in series

convenient in obtaining the transient response during the first few cycles, but as time goes on, the manipulation becomes more and more tedious and the result less and less accurate.

Current Response of Bi-Phase Controlled Rectifier

With an inductive load consisting of a resistance and an inductance in series supplied by a controlled rectifier of the gaseous discharge type, the current during successive conduction periods will be different after the closing of the switch if the conduction is continuous. It is required to find the transient current response at any instant during the existence of the nth rectified voltage wave after the closing of the switch.

Again starting with the analytical solution, the peak value of the anode voltage is A. The phase retard of the controlled rectifier can be expressed as θ_f electrical degrees. The time interval equivalent to 180 electrical degrees is t_1, and is equal to $\pi/\omega = 1/2f$. The beginning of nth rectified wave is taken as the zero axis of time.

Component Wave	Magnitude	Time at which Wave Starts	
		In Elec. Deg.	In Sec.
nth	$2A$	0	0
$(n-1)$th	$2A$	π	$-t_1$
$(n-2)$th	$2A$	2π	$-2t_1$
.....			
2	$2A$	$(n-2)\pi$	$-(n-2)t_1$
1	A	$(n-1)\pi$	$-(n-1)t_1$

The transient current response of an inductive load consisting of R and L in series to a unit sinusoidal wave closing at $\sin(\omega t + \theta_f)$ is[10]

$$i = \frac{1}{Z}\sin(\phi - \theta_f)\,\epsilon^{-\alpha t} + \frac{1}{Z}(\omega t - \phi + \theta_f) \qquad (6)$$

in which

$$Z = [(\omega L)^2 + R^2]^{0.5}$$
$$\theta = \tan^{-1}(\omega L/R)$$
$$\alpha = R/L$$

Then the current responses to component waves are

$$i_n = \frac{2A}{Z}\sin(\phi - \theta_f)\,\epsilon^{-\alpha t} + \frac{2A}{Z}\sin[\omega t - \phi + \theta_f]$$

$$i_{n-1} = \frac{2A}{Z}\sin(\phi - \theta_f)\,\epsilon^{-\alpha(t+t_1)} + \frac{2A}{Z}\sin[\omega t - \phi + \theta_f + \pi]$$

.....

$$i_2 = \frac{2A}{Z}\sin(\phi - \theta_f)\,\epsilon^{-\alpha[t+(n-2)\,t_1]} + \frac{2A}{Z}\sin[\omega t - \phi + \theta_f + (n-2)\,\pi]$$

$$i_1 = \frac{A}{Z}\sin(\phi - \theta_f)\,\epsilon^{-\alpha[t+(n-1)\,t_1]} + \frac{A}{Z}\sin[\omega t - \phi + \theta_f + (n-1)\pi]$$

$$t_1 \geqq t \geqq 0 \qquad (7)$$

The total current response is

$$i = i_1 + i_2 + \ldots\ldots\ldots\ldots + i_{n-1} + i_n$$
$$= \frac{2A}{Z}\sin(\phi - \theta_f)\,\epsilon^{-\alpha t}\left[\frac{1 - \epsilon^{-n\alpha t_1}}{1 - \epsilon^{-\alpha t_1}}\right] - \frac{A}{Z}\sin(\phi - \theta_f)\,\epsilon^{-\alpha[t+(n-1)t_1]} + \frac{A}{Z}\sin(\omega t - \phi + \theta_f)$$

$$t_1 \geqq t \geqq 0 \qquad (8)$$

The steady-state solution, with $n \to \infty$, is

$$i = \frac{2A}{Z}\sin(\phi - \theta_f)\,\frac{\epsilon^{-\alpha t}}{1 - \epsilon^{-\alpha t_1}} + \frac{A}{Z}\sin(\omega t - \phi + \theta_f)$$

$$\pi \geqq \omega t \geqq 0 \qquad (9)$$

Figure 11 shows the current responses to the component waves graphically. The exponential and sinusoidal components for each component wave are plotted separately. The resultant of exponential components, which is in the form of stepped exponential waves, is shown in Fig. 12(a). The sum of all sinusoidal components, which is a discontinuous periodic wave consisting of 180 electrical degrees of sine wave starting from $\sin(\phi - \theta_f)$, is shown in Fig. 12(b). The total response is the sum, shown in Fig. 12(c).

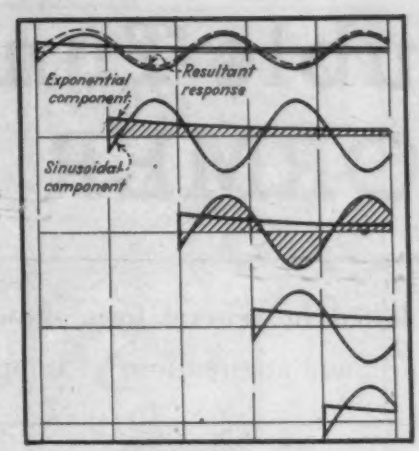

FIG. 11 (above)—Responses to component voltage waves of a controlled gaseous rectifier, for an inductive load

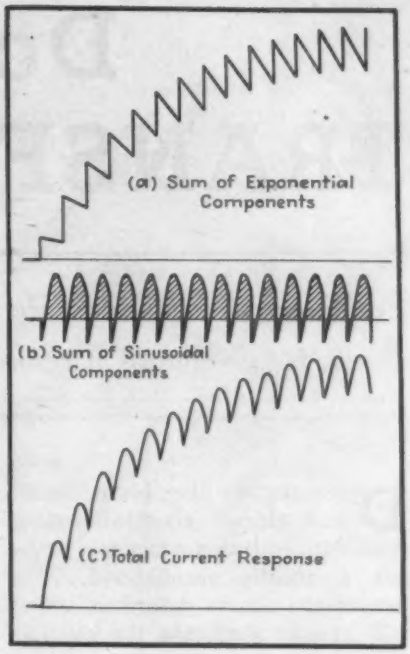

FIG. 12 (right)—Total response for arrangement of Fig. 11 is obtained by combining each type of component voltage separately, then combining the two resultant wave forms

Conclusions

The principle of decomposing some types of non-sinusoidal waves into waves of the same wave form but starting at different instants can be utilized as a short-cut method to obtain both the transient and the steady-state circuit responses to these waves.

The mathematical analysis involved in this method is comparatively simple and fundamental. It can be performed by those who do not have an adequate training in higher engineering mathematics, such as Laplacian transformation often used as a tool in solving problems of this nature.

The graphical analysis is very convenient for evaluating the transient response during the first few cycles, but may become more tedious and less accurate for evaluating the steady-state response, especially for circuits with large time constants.

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Double-Tuned TRANSFORMER DESIGN

Fundamental equations are plotted in general form showing the relations between k, Q, db, f/f_o, response at resonance, and attenuation. Examples illustrate use of curves

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DETERMINING the performance and circuit constants of a double-tuned transformer is a problem frequently encountered. The use of the charts described below will greatly facilitate the calculations.

The general expression for the attenuation of two identical coupled circuits is[1]

$$db = 20 \log \frac{\sqrt{4\left(Q\frac{\Delta f}{f_o}\right)^2 + \left[1 + (Qk)^2 - \left(Q\frac{\Delta f}{f_o}\right)^2\right]^2}}{2Qk} \quad (1)$$

This relation is plotted in Fig. 1 so as to give the level variation of a family of Qk curves with respect to $Q(\Delta f/f_o)$.

The coupling between the two coils, k, and the Q of the coils is related to width of the pass-band by[2]

$$\frac{\Delta f}{\sqrt{2}\, f_o} = \sqrt{k^2 - 1/Q^2} \quad (2)$$

where $\Delta f/f_o$ is the fractional frequency deviation. The $\sqrt{2}$ converts from peak separation to bandwidth[3]. The level change in the pass-band may be obtained by setting $\Delta f/f_o = 0$ in Eq. (1) and dividing the result by 2 in order to obtain the variation in gain from the average, as a function of coupling. This leads to

$$\Delta db = 10 \log \frac{(Qk)^2 + 1}{2Qk} \quad (3)$$

Equations (2) and (3) are plotted simultaneously in Fig. 2. This chart gives the solution of the problem involving the four variables k, Q, $\Delta f/f_o$, and Δdb, with any two of them known. Since k is usually an adjustable variable, there are three possible cases

Known	*Unknown*
(1) $\Delta f/f_o$ and Δdb	Q and k
(2) $\Delta f/f$ and Q	Δdb and k
(3) Δdb and Q	$\Delta f/f$ and k

The relative response at resonance, due to variations in Qk, is obtained from the reciprocal of the expression resulting from setting $\Delta f/f_o = 0$ in Eq. (1). This gives

$$\text{Gain reduction factor} = \frac{2Qk}{(Qk)^2 + 1} \quad (4)$$

The solid curve in Fig. 3 is plotted from Eq. (4). The factor used to determine the average gain in the pass-band, as a function of Qk, is obtained by averaging the gain reduction factors at maximum pass-band gain and at resonance. This yields

$$\text{Gain reduction factor} = \frac{(Qk+1)^2}{2[(Qk)^2 + 1]} \quad (5)$$

A plot of this expression for values of $Qk \gtrless 1$ is shown by the dashed line in Fig. 3.

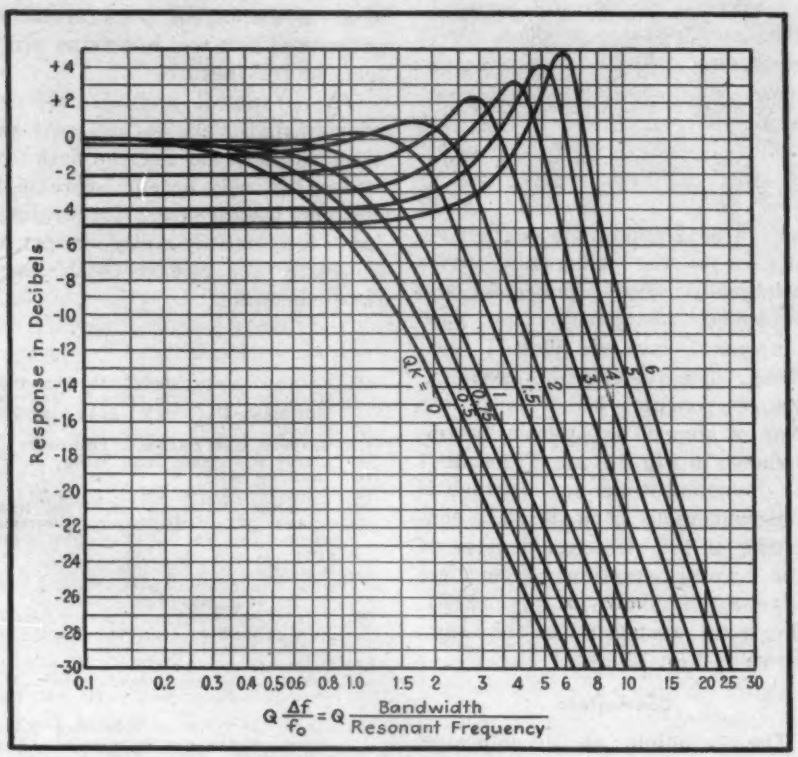
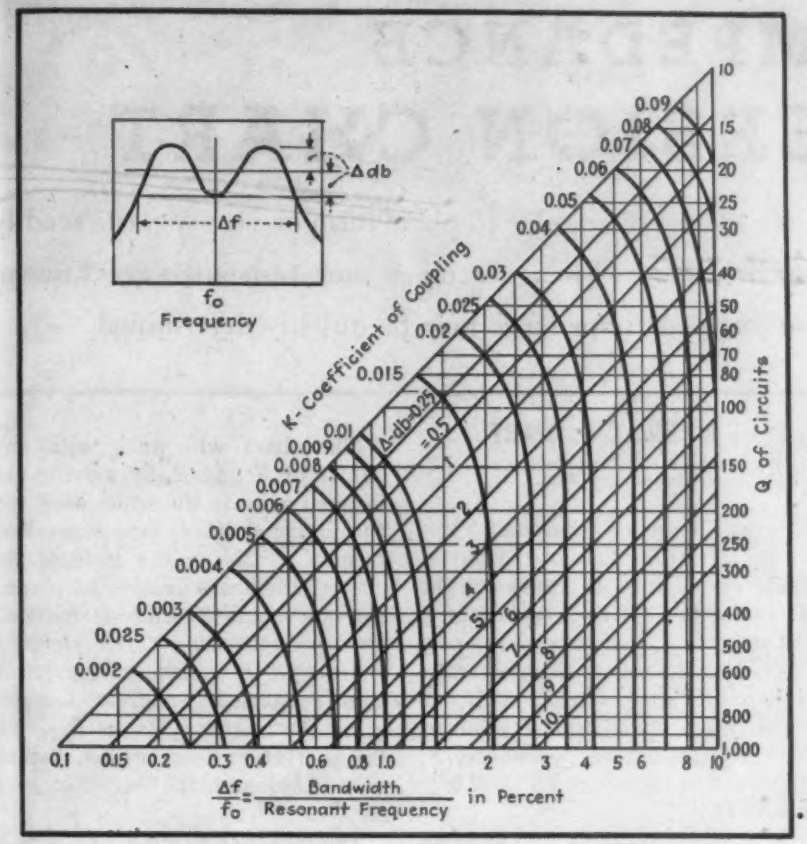


FIG. 1—Universal selectivity curves, showing deviation from average pass-band response vs deviation from resonance

Design Considerations

Design requirements of double-tuned r-f transformers ordinarily involve some particular attenuation at a given frequency-deviation from resonance. Knowing the required response in db, $\Delta f/f_o$, and the

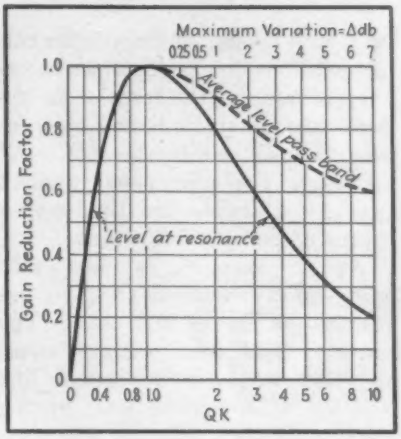


LEFT

FIG. 2—Three-parameter chart giving the relation between frequency deviation, coupling coefficient, and circuit Q for values of maximum response variation within the band

BELOW

FIG. 3—Output level plotted as a function of the product of coupling coefficient and circuit Q



available Q, the required Qk is determined from Fig. 1, and thus the value of k is found. If attenuation at a specific point has been the design criterion, the resulting Δdb can be determined from Fig. 2.

Frequently a transformer must be designed with a certain allowable response deviation from the average pass-band response. Usually the deviation, given in the charts as Δdb, the width of the band, given as Δf, and the resonant frequency, f_o, are known. By using Fig. 2, it is possible to calculate the corresponding Q and k. The resulting attenuation at various frequencies can be determined by the use of Fig. 1.

Design Procedure

1. Determine Q, k, $\Delta f/f_o$ and Δdb from Fig. 2.

2. Calculate maximum gain from $(g_m X_L Q/2)$ where g_m is the transconductance of the tube driving the transformer, and X_L is the reactance of either coil at f_o.

3. From Qk or Δdb, find the gain-reduction factor from Fig. 3 and multiply it by the gain obtained in step 2 to obtain actual gain.

4. Determine the gain at any portion of the response curve from Fig. 1.

Examples

1. An i-f transformer operating at 456 kc with a tube having a g_m of 3000 μmhos is required to have a pass-band of 16 kc. The response must not vary more than one db from the average. The inductance of each transformer winding is 250μh. Find Q, k, the average gain, and the attenuation at 20 kc from resonance.

Calculating $\Delta f/f_o = 16/456 = 3.51$ percent

From Fig. 2: $Q = 70$; $k = 0.028$

Max. gain $= g_m X_L Q/2 = 3000 \times 10^{-6}\ 2\pi 456 \times 10^3 \times 250 \times 10^{-6} \times 70/2 = 75.2$

Average gain in pass-band $75.2 \times 0.9 = 67.7$, where the 0.9 is read from Fig. 3.

For 20 kc deviation, $\Delta f = 40$ kc and

$(Q\Delta f/f_o) = (70 \times 40/456) = 6.14$

$Qk = 70 \times 0.028 = 1.96$

From Fig. 1 the attenuation = 18 db.

2. An i-f transformer is required to work at 3 Mc with a tube which has a g_m equal to 5000 μmhos, and using a 30-μh coil with a Q of 200. Find k and gain at resonance to give a compromise between gain and selectivity. Determine the gain at bandwidths of 10, 25, 50 and 75 kc.

A value of $Qk = 0.5$ is a good compromise between gain and selectivity, reducing the gain to 0.8 of the value obtained at critical coupling (Fig. 3), while improving the selectivity (Fig. 1).

For $Qk = 0.5$, $k = 0.5/200 = 0.0025$

Max. gain $= g_m X_L Q/2 = 283$

Gain at resonance $= 283 \times 0.8 = 226 = 47.1$ db

$Q/f = 200/3000 = 0.0667$

From Fig. 1

Δf in kc	10	25	50	75
$Q(\Delta f/f_o)$	0.667	1.667	3.333	5.000
Attenuation in db from Fig. 1	2.2	9.3	19.5	26.0
Gain in db: 47.1 minus Attenuation	44.9	37.8	27.6	21.1

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IMPEDANCE CONVERSION CHART

Conversion of complex quantities from rectangular to polar form or vice versa is readily accomplished, using only a straight-edge. When reactance and resistance are known, the magnitude and phase angle of impedance may be quickly determined

By PERRY H. WARE
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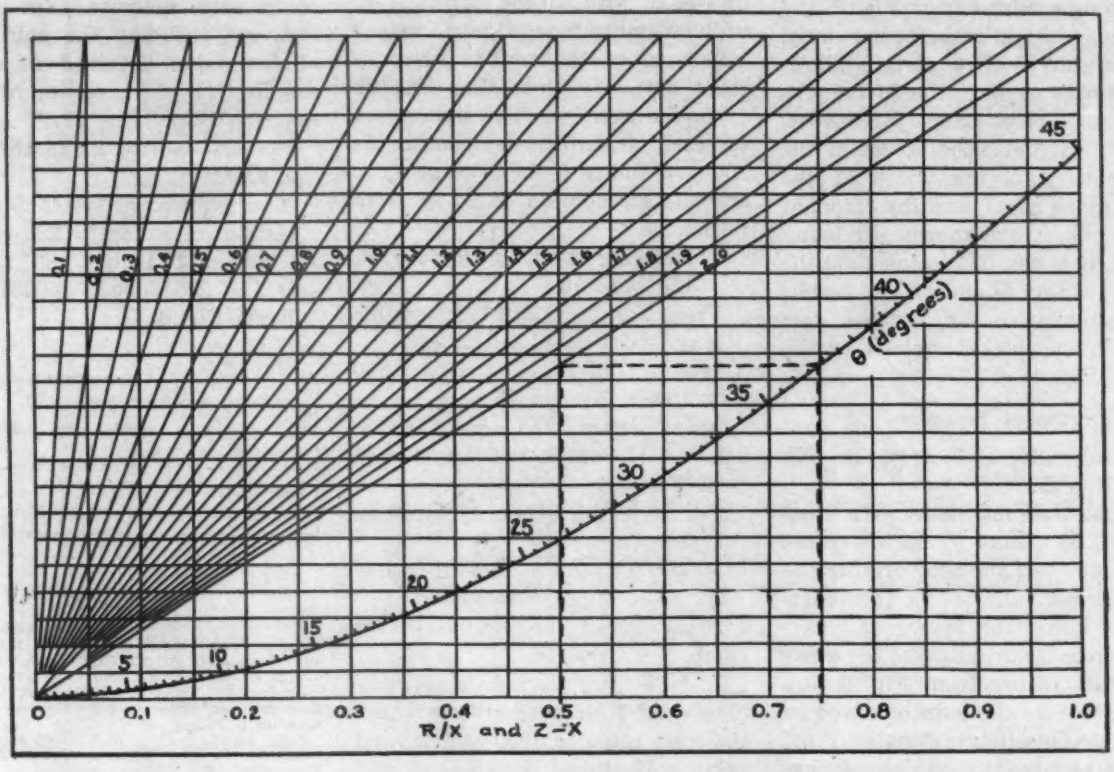
IN THE COURSE of impedance calculations, it often becomes necessary to transfer the form of an impedance from rectangular coordinates to polar coordinates ($R + jX = Z\angle\phi$). The accompanying chart provides a simple and time-saving means of making this change.

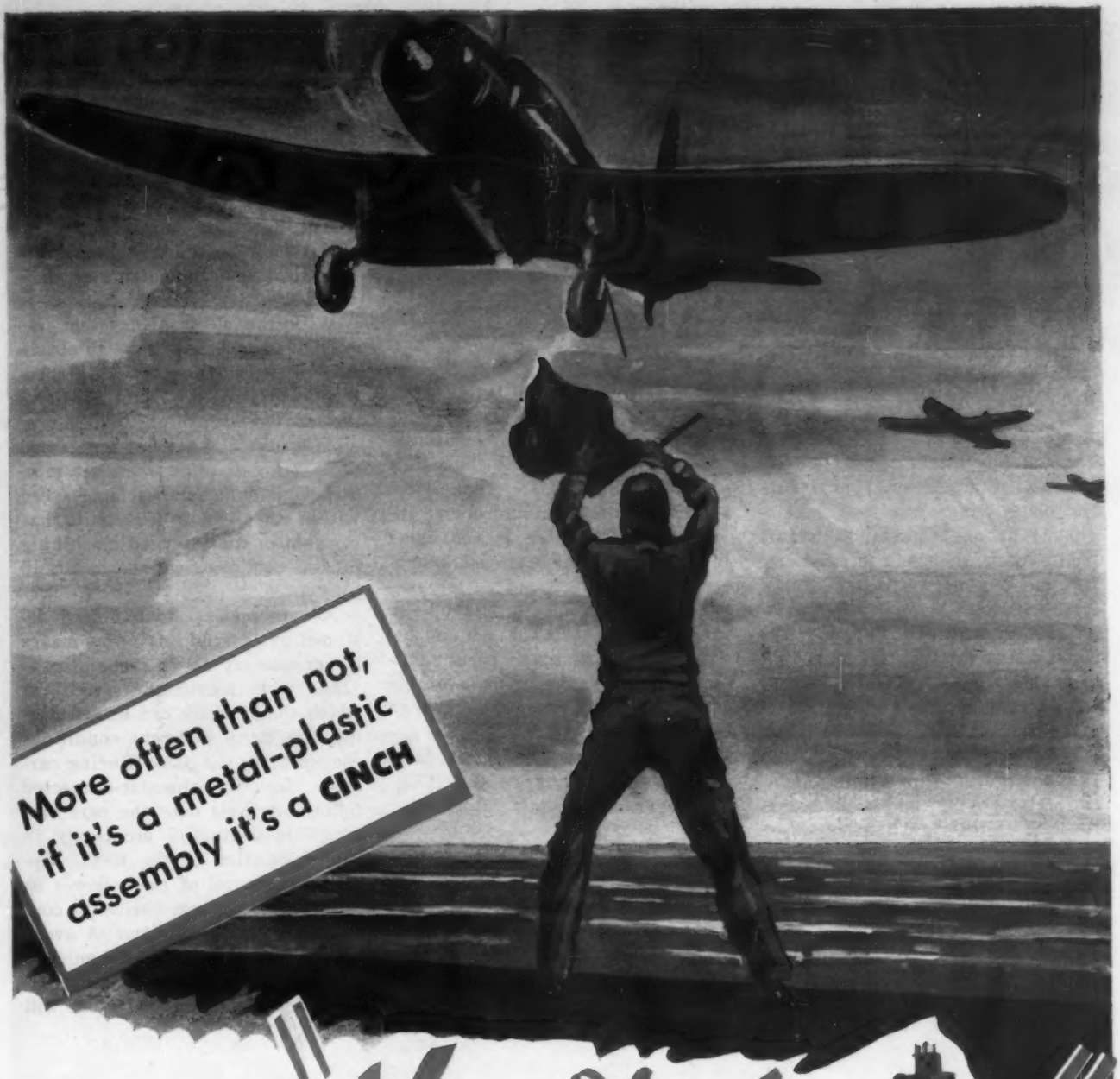
As an example, suppose that bridge measurements yield an impedance of $1.5 + j2.0$ ohms. The value of R/X is in this case equal to 0.75. Drawing a vertical line (shown as a dashed line on the chart) through 0.75 on the horizontal scale, it will be seen that this line intersects the phase-angle curve on the chart at a value of 36.9 degrees. This angle, θ, is the complement of the true phase angle, 53.1 degrees. Drawing a horizontal line to the left from 36.9 on the phase-angle curve until it intersects the diagonal line 2.0 corresponding to the value of X, then dropping a perpendicular to the horizontal scale, we obtain a correction $Z-X$ of 0.5, which when added to the value of $X = 2.0$, yields the impedance, Z, equal to 2.5; therefore $1.5 + j2.0 = 2.5\angle 53.1°$.

If R is larger than X, the ratio X/R is used as the original argument, and θ is the phase angle directly as read. The diagonal line corresponding to R rather than X is used, and correction is added to R.

The chart will work with any values of X and R, by moving the decimal point in the scales of X (on the diagonal lines) and correction term $Z - X$ (on the scale of abcissas) the same number of places, leaving the R/X scale as marked. For example, $20 + j15$ yields a value of $X/R = 0.75$, giving phase angle equal to 36.9 degrees. Considering the line $R = 2.0$ as $R = 20$, the correction term is 5.0, rather than 0.50, and the impedance is $25\angle 36.9°$.

The inverse operation ($Z\angle\phi = R + jX$) may also be carried out by means of estimated values, and practice will enable the user of the chart to carry out the computations quite rapidly.





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INDUSTRIAL CONTROL

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Machining Control Cuts Finishing Time

A REDUCTION in finishing time from 13½ hours to 5 minutes in the machining of aluminum spar beams for plane wings has been accomplished at one Cleveland aircraft plant, with the help of General Electric Thy-mo-trol installed on a large automatic contour milling machine designed and built by the Onsrud Machine Works, Inc. of Chicago.

The spar beams are long, one-piece structural channels which run lengthwise through the wing, from fuselage to wing tip. Wing ribs and cap strips are fastened on the beams to make up the rigid framework of the wing. The spar must be machined accurately to permit perfect joining of ribs and cap strips, and it must also be contoured exactly to conform with the irregular shape of the wing itself.

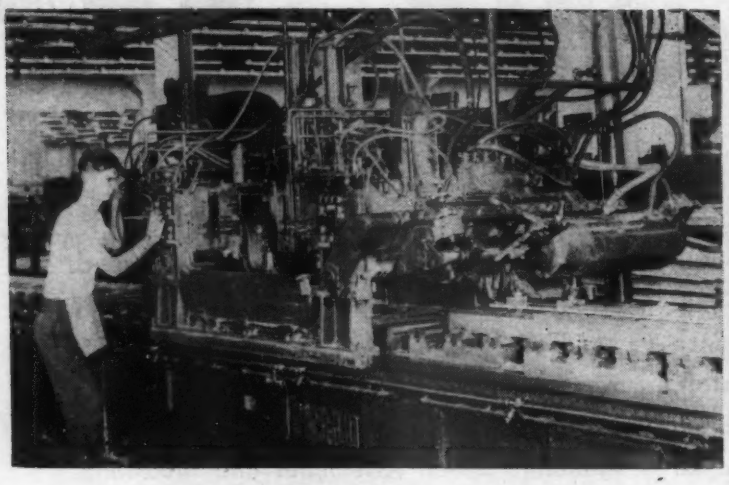
The carriage of the milling machine houses four cutter motor assemblies, providing two horizontal and two vertical cutters which turn at 3,600 and 10,800 rpm, ideal speeds for the aluminum alloys involved. Each cutter is controlled by a follower which travels over a template or former bar as the carriage moves from one end of the table to the other. The bed and table are long enough to permit machining the long spar in a single setup. With the four cutters, every type cut required by spar beam design may be made, such as face, slot, and side milling, twist cutting, beveling, and making cutouts for weight reduction.

Carriage Control

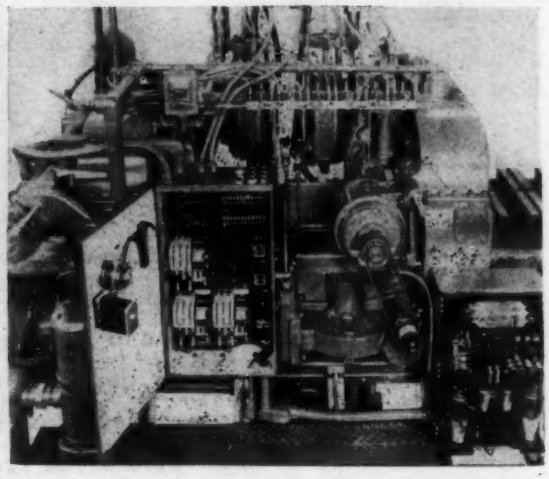
Need for a flexible carriage speed control was met by the Thy-mo-trol drive, which assures that the cutters are fed to the work at all times in proper relation to the changing contours of a spar beam. For example, in one pass over the table, the depth of cut may increase and decrease several times while the number of cutters entering the work may change from one to four. Such varying conditions required a change of feed to avoid overloading of the cutter motors. Moreover, a fast "skip" speed was essential to save time when no cutting at all is necessary.

With the electronic system, a-c power is converted to d-c to obtain a stepless speed range with a rheostat-controlled d-c carriage-drive motor. The control unit makes possible a carriage feed at any speed from 4 in. to 18 ft 6 in. per minute. This infinitely variable speed within the established limits has resulted in the topspeed machining of the complex spar beam at all times.

An automatic cam bar feed designed by Onsrud engineers makes it unnecessary for the operator to judge the maximum speeds at which the carriage can be fed during the many different conditions encountered in a pass. During carriage feed, a rheostat-connected follower travels over the cam bar, which is contoured accurately in proper relation to the work. Up-and-down travel of the follower as governed by the cam varies the control of the rheostat, and at every point of the pass the mechanically pre-determined carriage speed is at the exact maximum that work will permit.

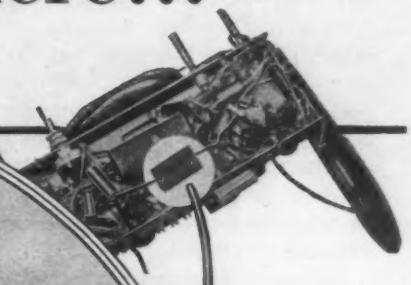


Automatic contour milling machine in operation. Equipped with G-E Thy-mo-trol, it does in 5 minutes a finishing operation in the machining of aluminum spar beams that formerly took 13½ hours



Close-up of G-E Thy-mo-trol panel and a-c magnetic controller (at left, door open) on the milling machine. The control panel at right without cover is for the 2-hp motor (center) which drives the carriage feed

Not Much Space Here...



But The P.R. MALLORY & CO. Inc. MALLORY Type WB Capacitor

Doesn't Need Much Space!

Keep Backing the Attack with War Bonds

MALLORY has pioneered the manufacture of dry electrolytics through the age of "specials" and individual specifications . . . can still supply them upon demand. But developments have proved that industry can best be served by standardized types of capacitors. The Mallory WB type capacitor is such a unit: an example, too, of careful design and production offering maximum capacity in a minimum amount of space.

Mallory type WB capacitors are housed in aluminum tubes that provide an effective seal against moisture absorption and loss of electrolyte. A cardboard cover provides excellent insulation against shorts when the aluminum tube is assembled in close quarters.

These electrolytic capacitors are ideal for applications in AC/DC sets and wherever space is at a premium. They are shorter than most cardboard tubulars that require extra length for sealing wax at either end.

These advantages—plus the hermetic seal of WB's—makes possible a tubular capacitor that withstands humidity and temperature changes harmful to most cardboard types. See your Mallory distributor or write direct for further information.

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

P.R. MALLORY & CO. Inc.

MALLORY

ELECTROLYTIC, FILM AND PAPER

CAPACITORS

Test Muzzle Velocity with Time-Interval Counter

AN ELECTRONIC INSTRUMENT that has been used for over a year at Aberdeen Proving Ground and other places instantaneously supplies information upon which the performance of a given gun is established and the uniformity of its ammunition checked within a few seconds. It is equally effective with all types of guns, from small hand weapons to 16-inch rifles.

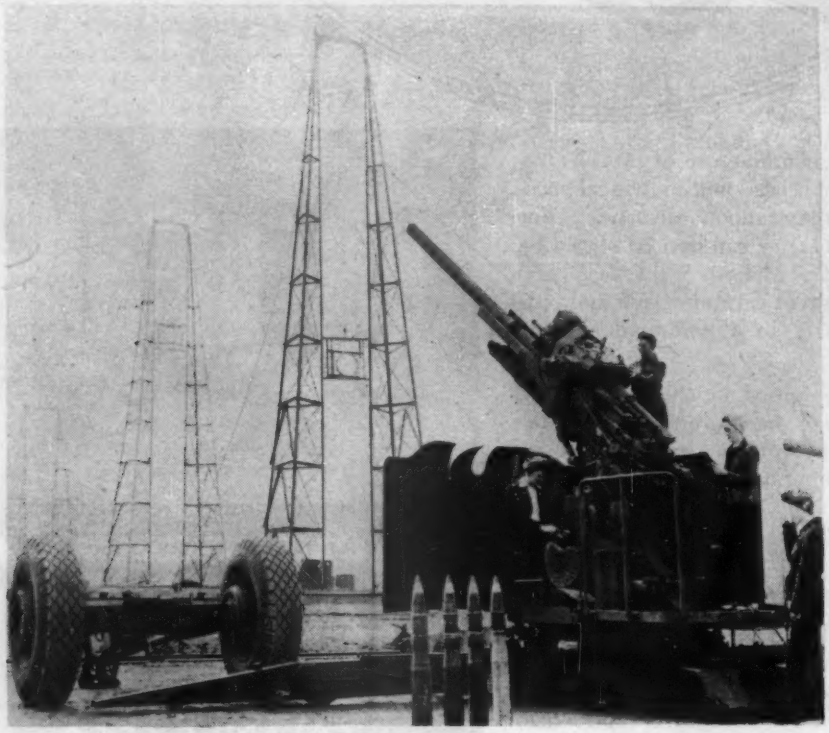
Developed especially for the Aberdeen Grounds by RCA Laboratories at Princeton, N. J., the electronic time-interval counter is designed to measure, with great accuracy, a time interval in the order of 0.01. Extreme accuracy is obtained through the ability of the device to give this measurement to within 0.00001 second. The research on this device was brought to fruition, and a very practical device made available to the military services through the work of Igor E. Grosdoff, RCA research engineer.

Principle of Operation

Each range is equipped with two electrical coils, arranged so that a projectile will pass through them in succession. By magnetizing the projectile, a small electrical signal is generated by each coil as the bullet passes through. If the coils are 30 feet apart, and the time between the two signals is 0.01 second, the bullet is traveling 3,000 feet a second. The measurements can be made at the rate of hundreds of observations a day.

The counter consists of three essential parts: an oscillator, a gate, and the counter proper. The frequency of the oscillator is controlled, as in a radio transmitter, by a quartz crystal ground to operate at precisely 100 kc. The gate is a vacuum-tube circuit which passes the pulses into the counter, which counts them and finally, when the gate is closed, shows by indicator lamps the number of pulses that have passed through. Thus, it shows the number of hundred-thousandths of a second from the time the gate opened until it closed.

In operation on the firing ranges, the counter's gate is opened by the electrical signal from the first coil as the bullet passes through it, and is closed again by the impulse from the second coil. The operator records the time of flight between coils and computes the velocity. It is noted down along with the record of the particular gun and projectile being tested for subsequent analysis by ballistic experts. The operator then touches the reset button and is ready to repeat.

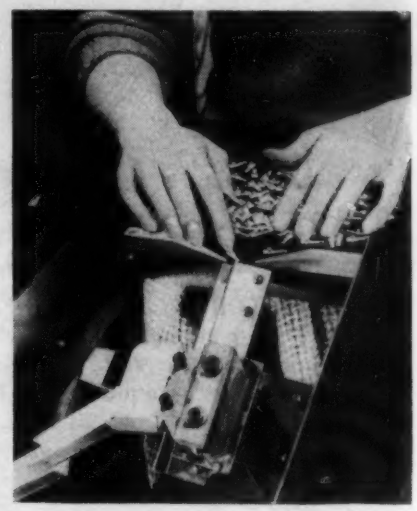


Shells from this 90-mm gun are magnetized, then shot through coils suspended from the towers. In passing through each coil, a voltage is generated and recorded on a chronograph. Electronic equipment permits determining the time interval to within a hundred-thousandth of a second

Electronic Sorting Table for Small Parts

MUCH GREATER SPEED in the sorting and inspection of tiny contact assemblies produced at General Electric's Schenectady Works has been made possible through the development of an electronic sorting table which routes the assemblies into three different channels depending on whether they are too high, too low, or within the tolerances.

Previously, the contact assemblies, each almost small enough to require handling with tweezers, were sorted and inspected by hand. Each assembly was checked with a needle micrometer to determine whether it was oversize, undersize, or within the tolerances, and then sorted accordingly.



Small assemblies being fed onto a slide for electronic sorting. The chutes for oversize and correct-size assemblies are located at lower left. Units that are too small travel the full length of the slide

The specially designed sorting table incorporates an electronic relay and a factory-constructed "contact head." Each assembly is fed

wherever a tube is used

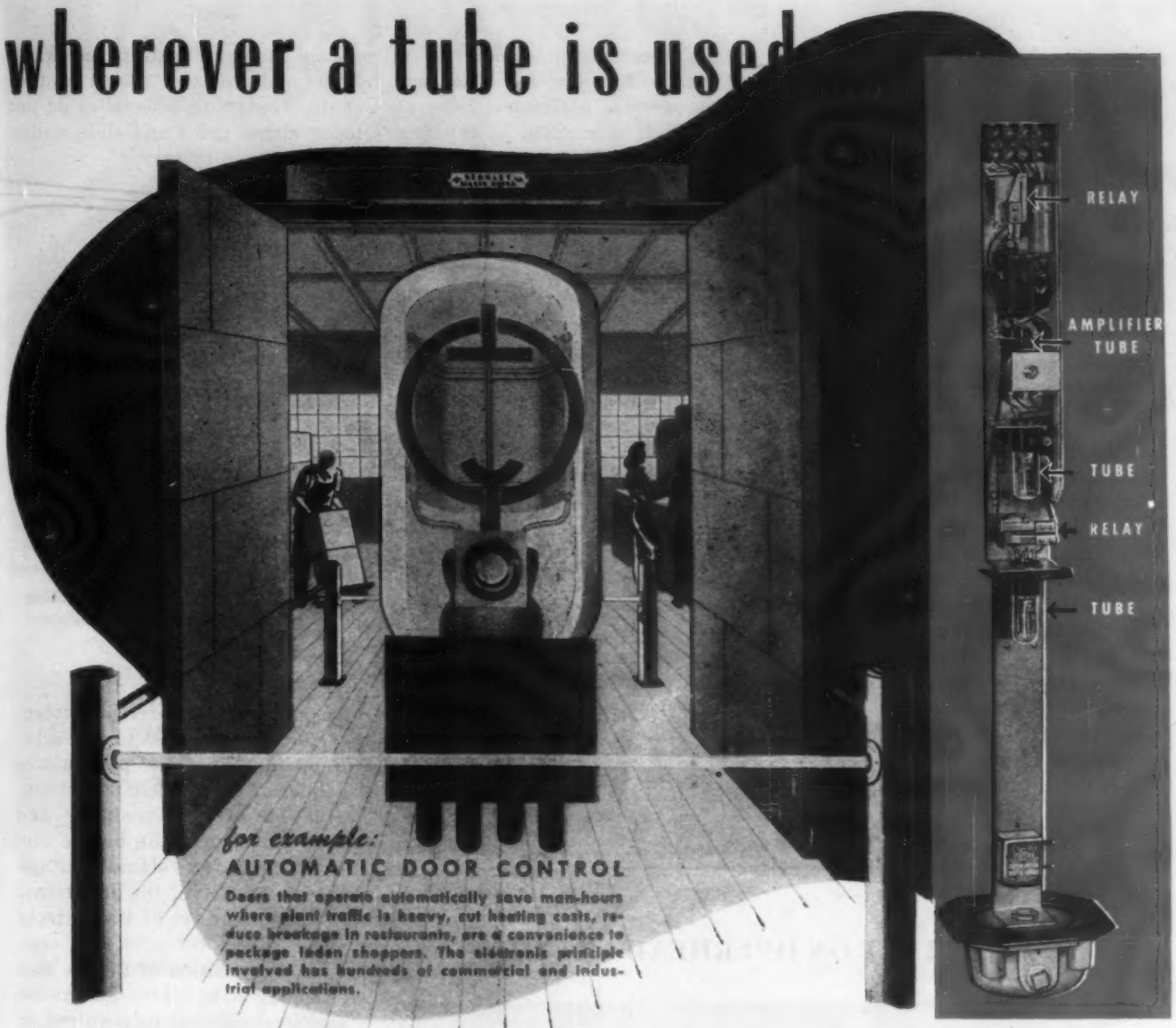

RELAY
AMPLIFIER TUBE
TUBE
RELAY
TUBE
for example:
AUTOMATIC DOOR CONTROL
Doors that operate automatically save man-hours where plant traffic is heavy, cut heating costs, reduce breakage in restaurants, are a convenience to package laden shoppers. The electronic principle involved has hundreds of commercial and industrial applications.

PHOTO-ELECTRIC DOOR CONTROL
Above unit manufactured by General Electric Co., is a part of STANLEY "MAGIC DOOR" CONTROLS.

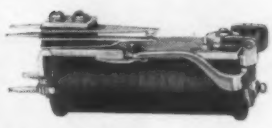
THERE'S A JOB FOR

Relays BY GUARDIAN

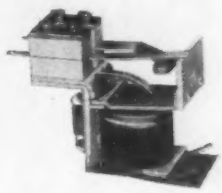
★ **The "Magic Door" made by The Stanley Works of New Britain, Conn., uses a General Electric control unit which operates automatically at the approach of a pedestrian or vehicle. In this unit a beam of light focused on the cathode of a phototube causes a tiny current to flow. Enlarged through an amplifier tube this current operates a sensitive telephone type of relay such as the Guardian Series 405. Another phototube with an auxiliary relay, Guardian Series R-100, is employed to hold the doors open for anyone standing within the doorway.**

The telephone type of relay is extremely sensitive and able to operate on the small current supplied through the electronic circuit. The auxiliary relay, Series R-100, is required to handle a greater current. It is a small, efficient relay having a contact capacity up to 1 KW at frequencies up to and including 28 megacycles. Contact combinations range up to double pole, double throw. Standard coils operate on 110 volts, 60 cycles, and draw approximately 7 V. A. Coils for other voltages are available. For further information write for Bulletin R-6.

Consult Guardian whenever a tube is used—*however*—Relays by Guardian are NOT limited to tube applications but are used wherever automatic control is desired for making, breaking, or changing the characteristics of electrical circuits.



Series 405 Telephone Type Relay



Series R-100 H. F. Relay

GUARDIAN ELECTRIC
1625-L W. WALNUT STREET CHICAGO 12, ILLINOIS
A COMPLETE LINE OF RELAYS SERVING AMERICAN WAR INDUSTRY

Close-up view of the work table for electronic sorting of small assemblies. At the right is the contact head and at the left is the electronic relay

onto a 45-deg slide which is part of the contact head. About halfway down the slide, the assembly comes to a contact point located at a preset height. If the assembly touches the point, it is oversize, and the contact made closes the grid circuit of a vacuum tube, which in turn energizes an electromagnetic relay. A solenoid is next energized, sending the assembly down a chute into a container for oversize parts.

A short distance beyond the first point, a second contact point is set at standard height less tolerance. Since oversize assemblies have already been eliminated at the first contact point, parts touching the second point are within acceptable limits and are "shot" down another chute. Undersize assemblies do not touch either point and slide undisturbed to a third tray.

Positioning Controls for Planes and Ships

FOR COMPLETELY ELECTRICAL remote positioning of rudders or other controls on airplanes or ships, it is possible to use a simple direct-current bridge circuit in which two potentiometers are connected in parallel across the d-c power source and the coil of a sensitive polarized or directional relay is connected to the movable contact arms of the potentiometers.

Figure 1 is a schematice electrical diagram of such a positioning control circuit. As shown here, the directional relay controls a reversible split-field direct-current motor with series-field windings F_1 and F_2. In this system, the transmitter, or control potentiometer P_T, is located in the cockpit, while the receiver, or position reference potentiometer P_R, is geared to the actuator motor. When the pilot moves the slider of transmitter potentiometer P_T to a new position, and thereby unbalances the bridge circuit, the resulting "signal" voltage applied to the coil of the directional relay causes one set of its contacts to close. These contacts then control the energization of the d-c motor, causing it to rotate (clockwise or counterclockwise) as required to move the actuator and the controlled aircraft members to the desired new position, corresponding to the pilot's setting of the transmitter control P_T.

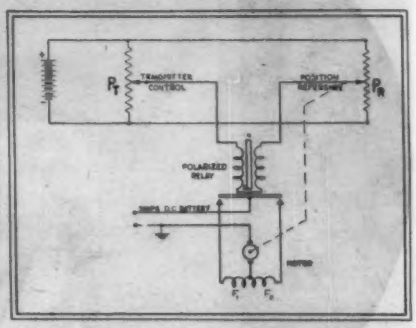
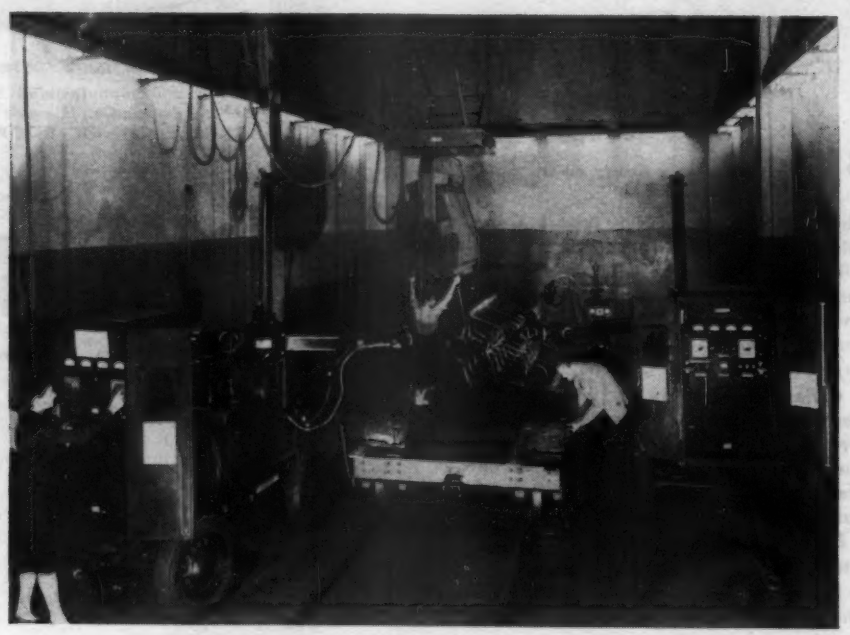


Fig. 1—Positioning control circuit using a balanced d-c bridge and polarized relay

The broken line connecting the motor and position reference potentiometer P_R represents the gearing which causes the motion of the slider of this potentiometer to be proportional to that of the controlled aircraft member and, therefore, when the latter reaches the desired position, the slider of potentiometer P_R matches the pilot's of P_T. The bridge is again balanced so that no further control signal voltage is applied to the coil of the directional relay, thus allowing its contacts to reopen. The motor is thereupon deenergized and the actuator remains in its new position.

Unless the relay is made exceptionally sensitive, the system shown is subject to positioning errors of

X-RAY UNIT ON OVERHEAD CRANE



Crankcases and other component parts for Navy ships are x-rayed for possible faults at Warren City Mfg. Co., Warren, Ohio. One of four of its kind in the country, the overhead x-ray equipment in the background can photograph steel plate up to 4 inches thick. Other portable industrial x-ray units appear in the foreground and extreme background

IRC WILL BE READY
WITH TOMORROW'S RESISTORS
FROM IRC ENGINEERING DEPT.
Just completed final tests on new
Resistors for [redacted] Company.
How many samples are needed?

In anticipation of "the day," alert manufacturers recognize the importance of lining up sound sources for the component parts they will require.

Right now, as for many months past, IRC research engineers are busily engaged in war development work on many new types of resistances which will fit the pattern of post-war applications. In addition, special design problems have been undertaken in instances where the prospective volume warranted such course.

That IRC will have in its expanded line most of the resistance devices industry will need, is assured as a result of careful market surveys. These quality units will be offered at prices consistent with mass production methods made possible through operation of the world's largest resistor plants.

If resistances will play a part in your post-war products, why not get in touch with IRC now? No obligation is entailed.

PREFERRED FOR PERFORMANCE
IRC
FIXED VARIABLE RESISTORS

INTERNATIONAL RESISTANCE CO.

401 N. Broad St. Philadelphia 8, Pa.

IRC makes more types of resistance units, in more shapes, for more applications than any other manufacturer in the world.

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Transformers
. . . Battle-Tested!
Before a Stancor Transformer is shipped, it is "certified for service" by engineers whose tests simulate actual conditions in the field . . . Because "Stancor" is battle-tested—right in our extensive laboratories—it has covered itself with glory on the battlefront. This is your assurance of the efficient performance of Stancor Products to which you may confidently look when the domestic market returns.
STANDARD TRANSFORMER CORPORATION
1500 NORTH HALSTED STREET • CHICAGO 22, ILLINOIS

the order of ± 2 percent to ± 3 percent of the total travel of the driven device. It is difficult in such a system to provide for antihunt or stabilizing means in the electric motor control. Thus, due to the inertia of the motor, the speed of operation of the controlled member has to be limited and the width of the null, or backlash, zone must be considerably wider than is necessary in a system that may incorporate a proper degree of "anticipation."

Electronic Positioning Control

To avoid using an extremely sensitive and delicate relay on an aircraft to obtain higher positioning accuracy and also to provide absolute stability and antihunt features, an electronic control circuit has been developed in which the sensitive relay is replaced by a vacuum-tube and differential-relay combination. Such a system was described by William P. Lear of Lear Avia, Inc., in a paper delivered at a joint meeting of the Franklin Institute and the Philadelphia section of AIEE.

Figure 2 shows a schematic diagram of a positioning control circuit using the electronic tube—relay system with a balanced alternating-current bridge connected to the secondary S_1 of power transformer T_1. In this circuit, the slid-

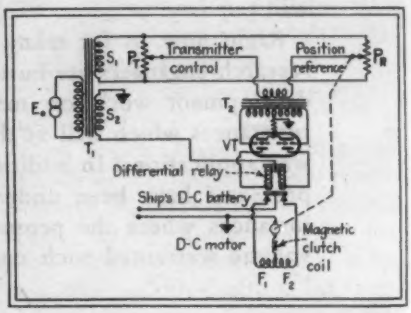

Fig. 2—Circuit of vacuum-tube system using an a-c bridge and relay for positioning control

ers of potentiometers P_T and P_R are connected to the primary of the grid transformer T_2, which "steps up" the weak signal voltage before it is applied to the grids of the vacuum tube *VT*. The differential relay coils, which are connected respectively in series with the plates of the tube, receive their power from the secondary S_2 of the power

. . . in Low and High Temperatures

There is a range of 210 degrees between the prevailing temperatures at the Equator and the Arctic Circle. Yet microphones must operate unfailingly, whether used at New Guinea or Murmansk. Shure Research, in heated chambers and dry ice temperatures, assures our armed forces Microphones that will bring the message through under any temperature condition. It's the same Shure Research that assures you a better postwar product.

SHURE BROTHERS, 225 West Huron Street, Chicago
Designers and Manufacturers of Microphones and Acoustic Devices

SHURE MICROPHONES

Announcing a change of name!

Henceforth, the Lafayette Radio Corporation (Chicago and Atlanta) will be known as the

CONCORD RADIO CORPORATION

CONCORD RADIO

The Lafayette Radio Corporation has, for 22 years, been one of the respected and well-known names in the field of radio and electronics. Our policies and our personnel, our reputation for integrity and outstanding service to our customers have enabled us to become one of the nation's great arsenals of radio and electronic equipment. During these critical war years, the Lafayette Radio Corporation has aided immeasurably in speeding the production of materials for Victory.

In announcing the change of name to the CONCORD RADIO CORPORATION, we wish to emphasize the fact that the name *only* will be changed. To the thousands of discriminating, merchandise-wise buyers in industry, government and elsewhere who are among our thousands of satisfied customers, we promise a continuance and broadening of our organization and our policies.

With the advent of new and greater horizons in electronics, the CONCORD RADIO CORPORATION will blaze new trails in engineering achievements and customer services. And, as always, complete satisfaction will be guaranteed in every transaction.

The CONCORD RADIO CORPORATION will, when the time is right, announce many unusual electronic developments. Watch our future advertisements in this, and other publications. And be sure that your name is on our list to receive our postwar literature and catlogs.

Just off the Press!

NEW, 16-PAGE "SPECIAL FLYER" . . . a last-minute compilation, by the CONCORD RADIO CORPORATION, of hard to find components and equipment for industry, service men, training schools, etc. MAIL COUPON TODAY.

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transformer. When the bridge circuit is balanced there is no a-c signal to the grids of the tube, and the relay coil currents are balanced. The relay contacts are open and the motor is de-energized.

When the pilot moves the slider of transmitter potentiometer P_T to a new position, the tube amplifies and rectifies the resulting unbalanced signal voltage, causing one relay coil current to increase and the other to decrease. The relay operates to energize the actuator motor, which then moves the driven aircraft component, and with it the slider of position reference potentiometer P_R to the position corresponding to that of the transmitter potentiometer P_T. The bridge circuit is again balanced so that no further control signal voltage is applied to the grids of the vacuum tube *VT* and the relay coil currents return to their balanced values, allowing the relay to open and stop the actuator in its new position.

Magnetic Clutch

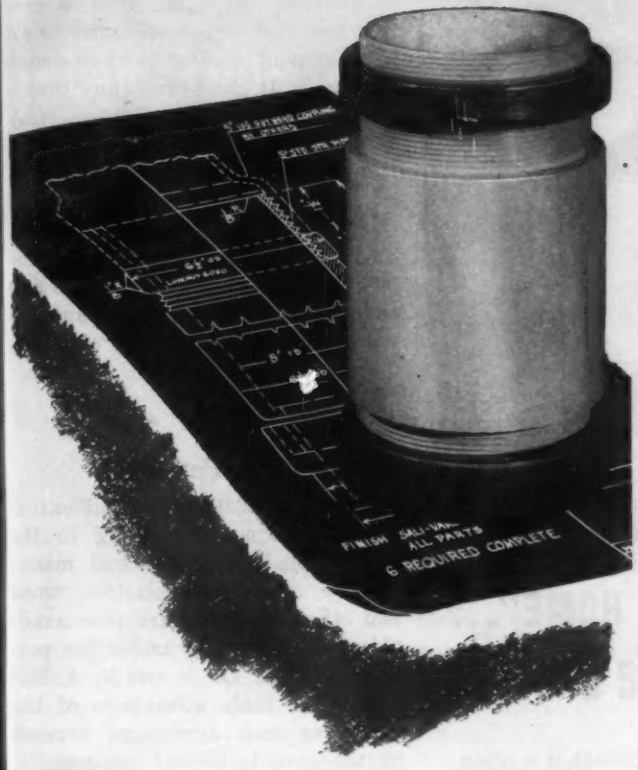
An important feature in stabilizing the operation of this control system is the use of a fast-acting, low-inertia clutch. One such clutch that has proven satisfactory in actual service is the Lear "Fastop" magnetic clutch which is electrically connected with the motor as shown in Fig. 2. As previously ex-

• • •

TWIST-TEST FOR C-R TUBES

After soaking in warm water for 18 hours, cathode-ray tube bases are inserted in the holder shown above and the tube twisted against the torque of the weight on the arm. Virginia Connick tests the cement on the tube base in this manner at the Dobbs Ferry plant of North American Philips

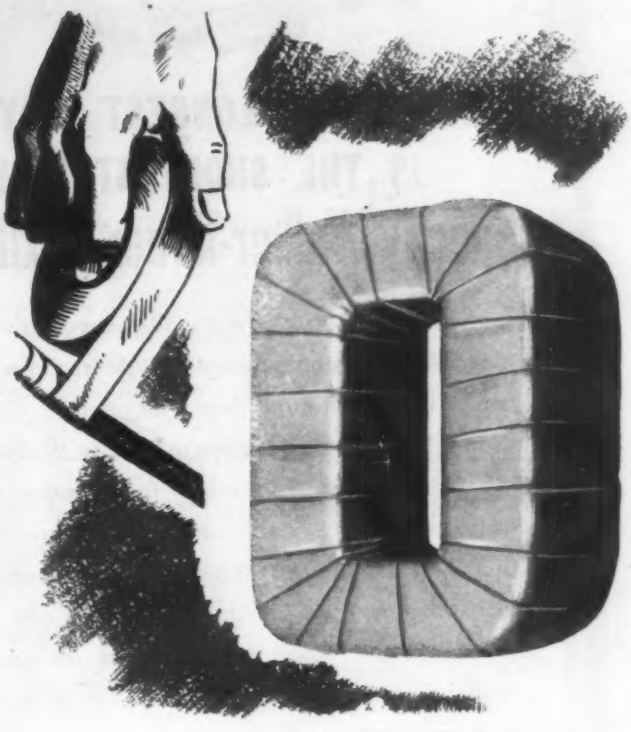
Electrical Equipment



Specially designed insulating parts machined from LAMICOID plastic laminates meet mechanical and electrical specifications not possible to obtain with a less versatile material. Lightness, structural and dielectric strength—machinability that permits fabrication into simple or intricate shapes, and dimensional stability—all make it ideal for fabrications of parts like that illustrated at left.

In addition to Mica Insulator Company's own plant in Schenectady, New York, expert fabrication facilities are available through LAMICOID fabricators, strategically located in large industrial centers (see addresses below).

These plants maintain large stocks of LAMICOID sheets, rods and tubes, and offer prompt delivery of LAMICOID fabrications of all kinds.



Of particular interest is this new EMPIRE "3 mil bias tape" which combines extreme thinness with excellent dielectric strength and elongation properties. It is especially adapted for use on irregularly shaped conductors; or for solenoid and instrument coils.

The EMPIRE line also includes a complete line of varnished cloths and tapes and Varnished Fiberglas (for Class B insulation).

FABRICATORS

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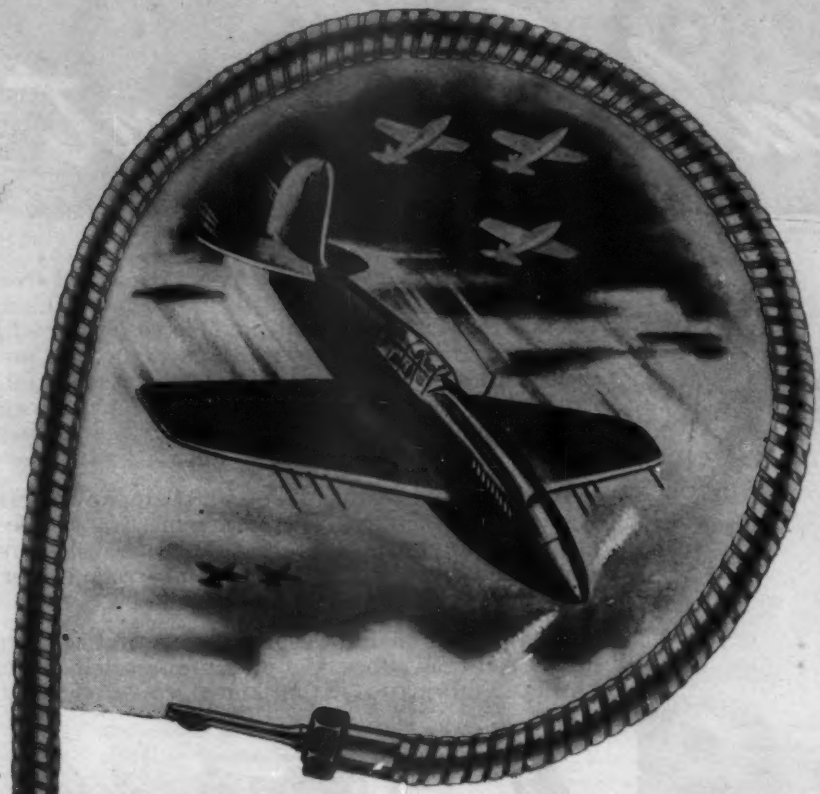
INSULATOR COMPANY

200 VARICK STREET, NEW YORK 14, N. Y.



WHEN THE "LONGEST WAY 'ROUND IS THE SHORTEST WAY HOME"...

Specify Walker-Turner Flexible Shafting

In transmitting light power loads between two points, it is often possible to design a simpler, lighter, more compact product with Flexible Shafting than with gears.

You'll find, too, that it pays to specify Walker-Turner Flexible Shafting on jobs like these — for smoother power flow, more sensitive control, trouble-free operation. Into this product, we've packed all the "know-how" picked up in years of manufacturing our own flexible shaft machines . . . in years of working with other manufacturers on problems of power transmission and remote control. Let us know if we can put that experience to work for you!

WALKER - TURNER COMPANY, INC. Plainfield, New Jersey

walker-Turner COMPANY, INC. PLAINFIELD, N.J. U.S.A.

FLEXIBLE SHAFTING

FOR REMOTE CONTROL AND POWER TRANSMISSION

6-12

plained, this clutch disconnects the motor from the gearing actuator immediately upon de-energization of the motor and also permits the clutch member to brake the gearing, whereby the actuator and airplane member are almost instantly stopped. Other features will increase the stability or anti-hunt characteristics of the control system and can be incorporated in an arrangement similar to that shown in Fig. 2. It has been found that a potentiometer-vacuum - tube - relay control system, as exemplified by Fig. 2, can position remotely to accuracies well within one percent of the total travel of the driven device. Such accuracies are ample for the positioning of most accessories and components on an aircraft, such as wing flaps, landing gear, shutters, doors, cowl flaps, etc.

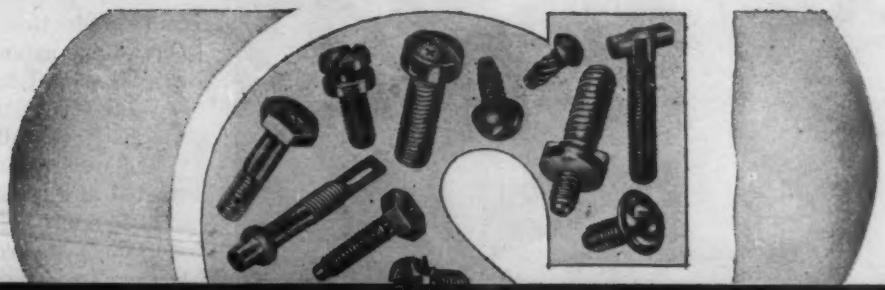
• • •

H-F Heating Patents

LICENSES COVERING the application of high-frequency heating in the production, processing and manufacture of rubber, plastics, wood and other products, are now available in this country under the patents of H. A. Leduc and R. A. Dufour. The main advantage of the processes and apparatus covered by the patents is that non-metallic dielectric materials can be rapidly and uniformly heated throughout their mass, and that temperature and temperature rise can be accurately controlled.

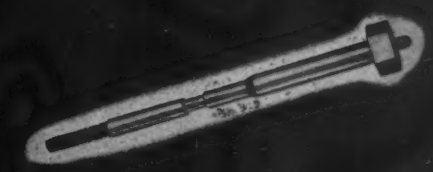
Originally developed by the inventors with a view to overcoming the difficulties inherent in the vulcanizing of massive rubber objects, the high-frequency heating process has become the means for making possible heat transfer in many poorly conducting or non-conducting materials.

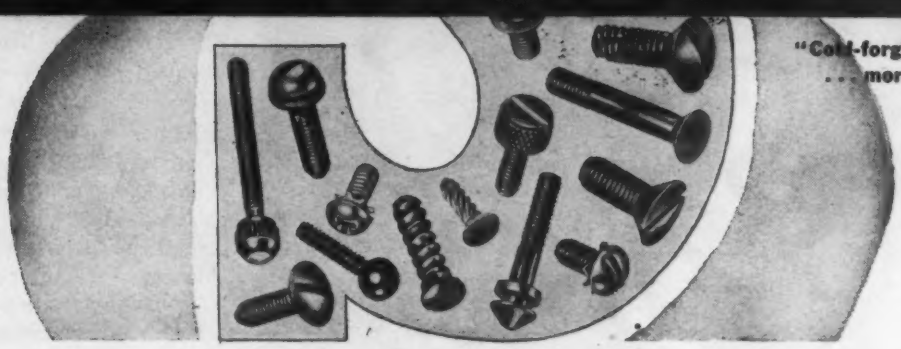
According to the claims, the practical applications of the process in the rubber field include: thermal plasticizing of bales of raw rubber; reclaiming by heat; vulcanizing of sponge, thick masses, roll coverings, rubber-coated metals, rubberized or plasticized parts, proofed goods and molded articles; concentration, sterilization and vulcanizing of stabilized latex; coagulation of heat-sensitized or electrically unstable latex; manufacture of insulated cables and wires



PLAN YOUR FASTENINGS NOW

For that Product in the Design Stage





"Cold-forging"—proof #24 . . . more each month

Plan now for fast assembly of your product before it leaves the design stage. Your preparation for postwar production should include an early and exacting choice of fastenings—standard or special—to eliminate unnecessary assembly problems later. Remember, your precise selection may be "the making" of your assembled product—for no product can be better than its fastenings.

Now is the time to let Scovill's broad experience in fastenings and skill in special design serve you. We will help you determine the best modern fastenings to use—one of our featured standard fastenings, or a part specially designed to fill your specific need.

A substantial saving was effected by cold-forging the unusual part shown above. You likewise may profit through Scovill ingenuity in cold-forging . . . saving money—materials—motions. Call our nearest Fastenings Expert **now** for assistance in planning your fastenings.

3 Standard Fastenings for Production Efficiency

1 Phillips Recessed Head Screws—The modern, effective, time-saving fastening device proven in tens of thousands of assembly lines. Other standard head styles are available.

2 Self-Tapping Machine Screws—Eliminate separate tapping operations for fastenings to castings, heavy gauge sheet metal, and plastics. Also with Phillips Recessed Head.

3 Washer-Screw Assemblies—When use of lock washers is indicated, the time-saving of pre-assemblies is obvious. Also available in standard slotted head styles.

SCOVILL MANUFACTURING COMPANY

WATERVILLE SCREW PRODUCTS DIVISION

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and production of latex sponge. One of the patents is claimed to be a basic patent for coagulating any "coagulatable fluid material", from spaghetti to wallboard.

Leduc's invention was demonstrated at the Exposition of Paris in 1935 and the French Rubber Association honored him with its medal. In a report to the French Senate, it was stated that the Dufour-Leduc inventions alone justified the more than 20 years of operation of the immense Government Research Center. In this country, the B. F. Goodrich Co., Akron, Ohio will issue licenses covering rubber applications. W. H. Giodvad Grell, 33 University Place, New York 3, N. Y. will issue licenses in all other fields.

Advantage

Since the discovery of vulcanization in 1839, rubber has been vulcanized by applying steam heat to the outside surface of a rubber article and depending upon conduction to carry the heat into the rubber. Owing to its poor heat-conducting characteristics, the rubber was not heated uniformly and, in many cases, inferior articles were produced. In the electronic vulcanizing method, heat is generated inside the body of rubber so that large masses of rubber may be vulcanized quickly and uniformly.

Already finding extensive commercial application in the rubber and other industries, the electronic process promises to be used not only for vulcanizing rubber articles but also for the vulcanization of thermosetting materials. In many cases, the duration of the "cure" may be shortened enough to permit continuous conveyor vulcanization where such practice would not be feasible otherwise.

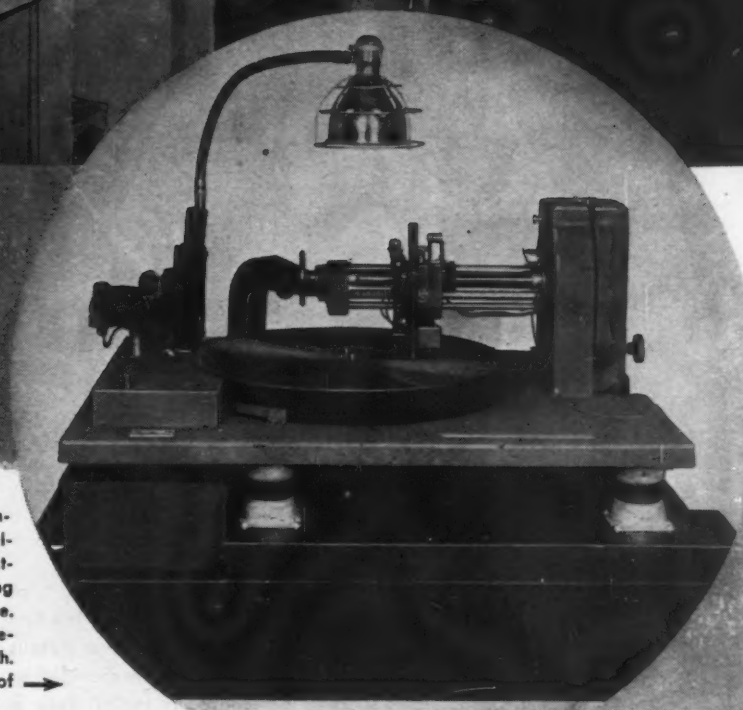
• • •

Electronic Induction Heating on Production Line

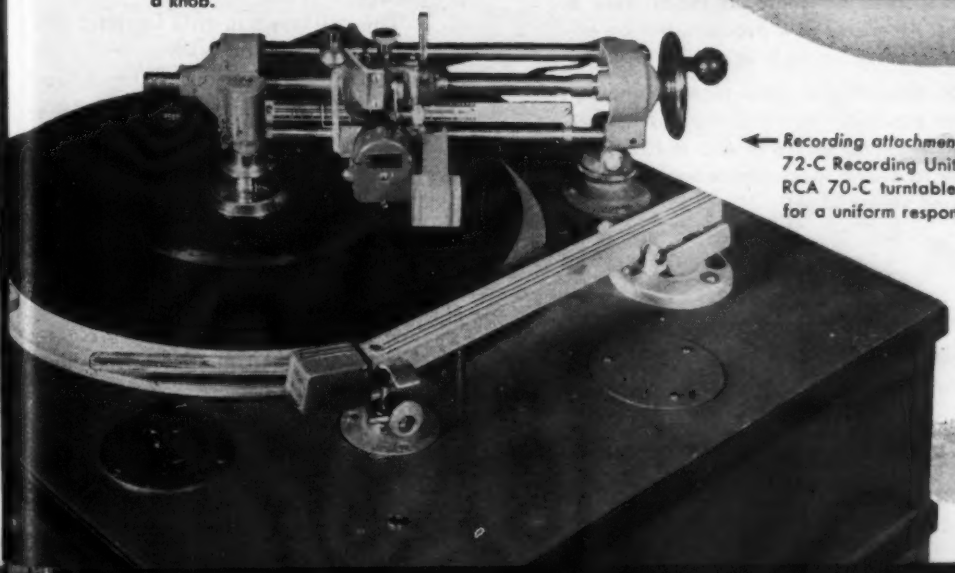
HIGH SPEED ELECTRONIC heating on a production line has been established for case-hardening finished bearing pins to a depth of 0.025 in. The pins were fed automatically through a glass tube and quenched with water as they left the heating coil at a rate of 75 pins per minute.

The r-f generator operated at a frequency of 5 megacycles and

Pictured here is the recording lathe bank at OWI Headquarters, New York City. These RCA recorders are used in making transcriptions of OWI news and entertainment programs for overseas broadcasting.



Close-up view of the RCA recording model employed at OWI Headquarters. A professional-type unit, the 73-AX Recorder provides highest-quality, instantaneous recordings for broadcasting purposes. 30 to 10,000 cycle frequency response. Records at 33⅓ or 78 r.p.m., outside-in or inside-out at 96, 112, 120, 136 or 154 lines per inch. Speed and groove adjustments at the turn of a knob. →



← *Recording attachment for turntable mounting.* The Model 72-C Recording Unit for control room use with standard RCA 70-C turntable equipment. Cutting head provides for a uniform response from 60 to 6000 cycles.

teepees were tied with thongs . . .

BUT NEW PRODUCTS NEED NEW FASTENINGS

With keen competition that must follow the first rush of peacetime business, important details will influence sales, promote merchandising, stimulate success. Of these, a major item is fastenings. America's new products will be efficient, economical, accessible.

Camloc engineers showed plane manufacturers that easily operated doors and removable panels can be secure at 400 M.P.H. They are ready to design special fastenings for your product and your budget.

CAMLOC

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420 LEXINGTON AVENUE, NEW YORK 17, N. Y.

heated the surface of each pin above its critical temperature in less than one second. At this speed of heating, there was insufficient time for the heat to penetrate into the core and only a thin surface layer experienced a change in physical state. The central portion of the parts retained all their original toughness and strength.

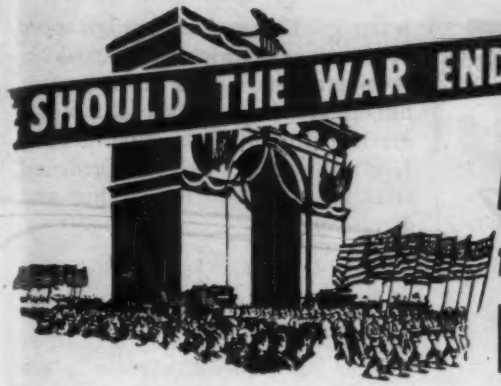
The factory application of this process to the continuous production line surface hardening of bearing pins involved the following equipment: the hopper from which the unhardened parts are fed into

Case-hardening of chromium-molybdenum steel bearing pins with a 5-Mc r-f generator. Inset at right is a microphoto of the hardened surface. The white portion is the outside case which has a thickness of 0.025 in.

the glass tube; the heating coil; a Megatherm induction unit manufactured by the Federal Tel. and Radio Corp.; a connection providing a continuous flow of water for quenching, and a work table with suitable containers for hardened pins as ejected from the heating fixture.

The coil used in this bearing pin application contains five turns of small copper tubing wound in a single layer approximately 1-in. long by $\frac{3}{4}$-in. in diameter. The coil is grounded and does not carry high voltage. It is exposed to continuous wetting by the water used for quenching.

The metal was chromium molybdenum steel NE-9442 and the surface hardness developed was Rockwell C 60—about file-hardness. The pins were finish ground prior to heat treating, and, after the hardening process, there was no scale or



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Whatever the application—no matter how exacting the specifications—ELCO will deliver resistors as you want them—when you want them.

FOR TODAY'S WAR REQUIREMENTS—
FOR TOMORROW'S PEACE NEEDS—
specify ELCO!

SPECIFICATIONS:

"A-1"—15/32 long x ½" dia.—Mountable with 6-32 flat or filester screw. No. 21 tinned copper wire leads. 1 to 300,000 ohm value—½% standard accuracy—non inductive pie wound—½ watt. 30° C. temperature rise in free air—100° C. maximum operating temperature—200 D. C. maximum operating voltage. Baked varnish finish.

"A-R"—Same as A-1, with leads reversed.

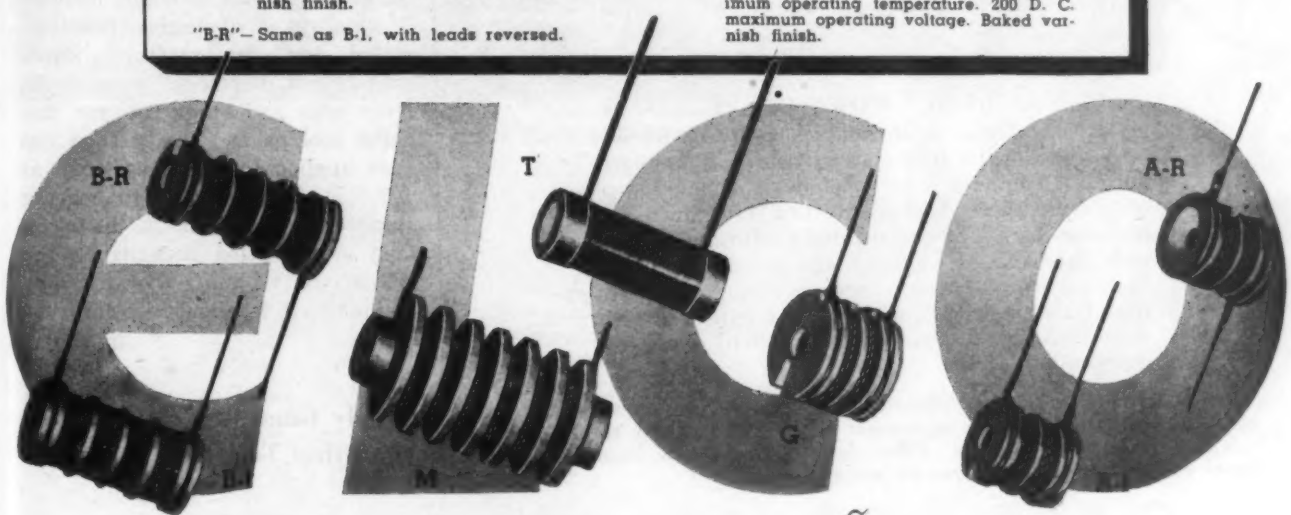
"B-1"—15/16 long x ½" dia.—Mountable with 6-32 flat or filester screw. No. 21 tinned copper wire leads. 1 to 500,000 ohm value—½% standard accuracy—non inductive pie wound—1 watt. 30° C. temperature rise in free air—100° C. maximum operating temperature—300 D. C. maximum operating voltage. Baked varnish finish.

"B-R"—Same as B-1, with leads reversed.

"T"—1-1/32 long x 7/16" dia.—Inductively wound—⅛ x .015 strap terminals—35 to 35,000 ohms—2 watts. 100° C. maximum operating temperature—normal accuracy 1%. Baked varnish finish.

"M"—1-13/32 long x ¼" dia.—Mountable with 6-32 screw—⅛ x .015 thick strap terminals—non inductive wound—1 meg ohm maximum resistance—600 volts maximum operating voltage—100° C. maximum operating temperature—1.5 watts—1% normal accuracy Baked varnish finish.

"G"—15/32 long x ½" dia.—Mountable with 6-32 flat or filester head screw. No. 21 tinned copper wire leads. 1 to 500,000 ohm value. ½% standard accuracy—non inductive pie wound .8 watts. 30° temperature rise in free air. 100° C. maximum operating temperature. 200 D. C. maximum operating voltage. Baked varnish finish.



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Add Another Star to Your America Show!

PRODUCED BY STATION WOW, OMAHA, FOR THE UNION PACIFIC RAILROAD ON NBC NETWORK SATURDAYS AT 4 P. M. (CWT)

A WOW control operator shown at Gates Console while airing "Your America" show.

"Behind the scenes," WOW's Gates Console is giving an all-star performance. The Model 30 is designed with true showmanship in appearance . . . engineered for efficiency that is paying off during these days when "the show must go on"—*or else!* The remarkable performance records these Gates Consoles are providing more than six-score stations, are convincing evidence that Gates studio equipment is engineered for dependability you get today and will want tomorrow.

Wartime restrictions do not allow the sale of new broadcasting equipment without priority. This equipment is presented merely to acquaint you with Gates developments. ***(May we send you details regarding the Gates Priority System for prompt postwar delivery?)***

Gates RADIO and Supply CO.

QUINCY, ILLINOIS U. S. A.

MANUFACTURERS OF RADIO BROADCAST TRANSMITTERS, SPEECH EQUIPMENT RECORDING APPARATUS AND ALLIED EQUIPMENT IN THE ELECTRONICS FIELD

warpage. This was due to high speed of the process which makes possible the surface hardening of parts after finish grinding. This eliminates much costly finishing which heretofore has been required on hardened steel parts because of sealing and distortion.

Depth of Treatment

The microphoto insert in the illustration shows a highly magnified view of the hardened surface as developed on the bearing pin. The white portion is that of the hardened outside case, and it will be observed that it extends a distance of 25 thousandths of an inch beneath the surface. Of this 25 thousandths, there is no visible change in the structure or depth of approximately 15 thousandths of an inch. From this depth in, there is a slight change in the apparent structure in the material, but there was no measureable loss of hardness insofar as was determined with a carefully conducted superficial Rockwell test. The dark portion is that of the unaffected core material. At no point in the transition zone from fully hardened case to the dark unaffected core material was there any evidence of softening or tempering of this adjacent internal layer.

The bearing pin application is only one of a family which includes a wide range of shafts, bearings, round and flat surfaces, zones, spots, cam surfaces, gear teeth, lever ends and other common machine tool parts. The method has been applied to pieces as small as $\frac{1}{8}$ in. in diameter and to bearing surfaces up to 6 in. in diameter. Cost of operation depends on the size of the r-f unit, with a 25-kw oscillator, it is about 50 cents per hour.

• • •

Handy Gage for Vibration Testing

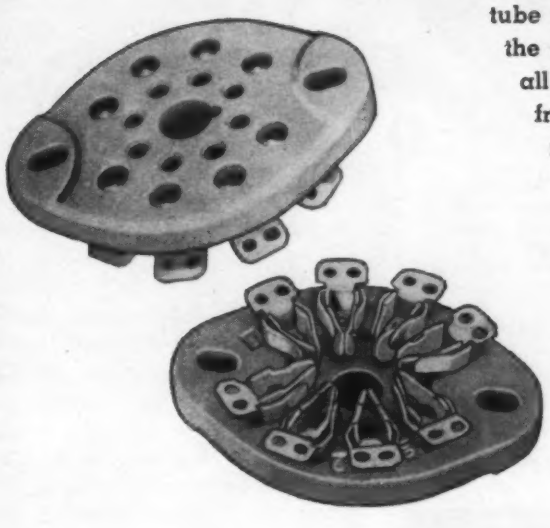
By F. R. Jessop

Examiner 1/C Type Tests
Inspection Board of United Kingdom and Canada
Northern Electric Co., Ltd.
Montreal, Que.

BECAUSE ELECTRONIC EQUIPMENT for the armed forces must perform under the severest operating conditions, all production is subjected to vibration testing. The device to be described has proven very useful

ENGINEERED

For a wide variety of applications



Each field of electronic design can fill its needs for correct vacuum tube receptacles with National Fabricated Sockets . . . To meet the demand for the ever-increasing variety of sockets covering all frequency applications, insulations are available ranging from paper base laminated phenolic sheet to mica-filled molded plastics and low-loss ceramics . . . Contact alloys of special steels, brasses, phosphor bronze, silica bronze and beryllium copper are employed — utilizing an assortment of mechanical contact designs to fill all wiring requirements and provide dependable long-life electrical performance.

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If your product or the one you are developing can be improved by the use of plastics with high structural strength, let a Richardson Plastician help you. Or, if resistance to chemicals, dielectric qualities, or moisture resistance is required, let him suggest the correct type and grade to meet your individual requirements. His years of experience may save you time and money. Write for complete information.

Laminated INSUROK has won the preference of many designers because of its favorable weight to strength ratio. Molded INSUROK is often preferred because of the intricate shapes which can be produced in one molding operation—eliminating assembly and manufacturing operations.

INSUROK *Precision Plastics*

The RICHARDSON COMPANY

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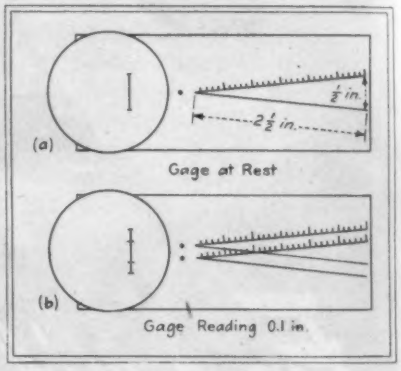
DETROIT OFFICE 6-252 G. M. BUILDING, DETROIT 2, MICHIGAN NEW YORK OFFICE 75 WEST STREET, NEW YORK 6, N. Y.

for determining the direction of maximum displacement and to accurately measure that displacement to 0.005 in. It is especially useful when it is necessary to take measurements at various points on equipment when studying the effect of shock mounts.

The device consists of a small disc riveted at one end of a rectangular card as shown at (*a*) in the illustration. Both the disc and the rectangular piece may be made of stiff fiber, plastic or metal. The assembly is secured to the apparatus under test by means of scotch tape or other adhesive.

On the disc is drawn, slightly to one side of the center, a capital letter *I*. This is made equal in height to the extreme displacement to be measured during the test. When used in conjunction with a Strobotac, this letter indicates the direction of maximum displacement. This is indicated when the two serifs of the letter *I* (made visible when the Strobotac is set at double the frequency of vibration) are farthest apart. The direction is that of the upright portion of the letter, as shown at (*b*) of the figure where the vibration is purely vertical.



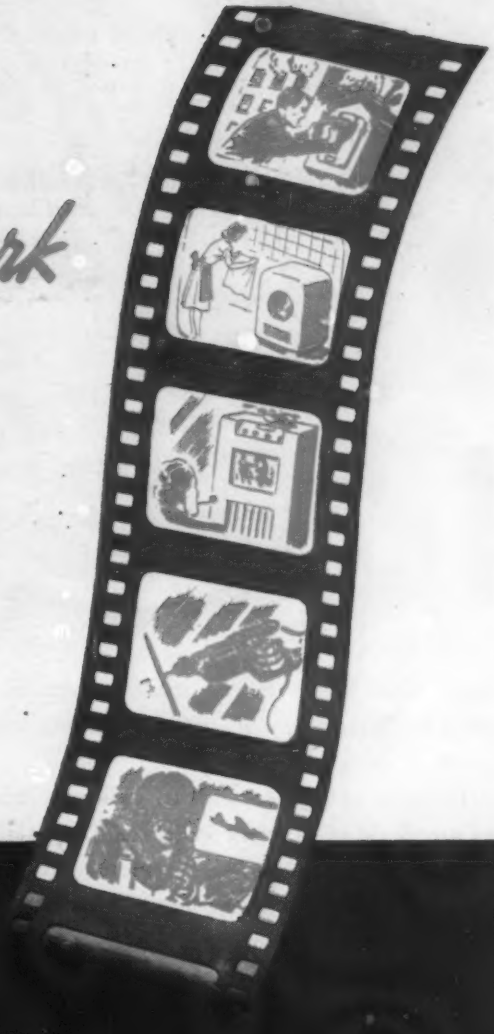
Gage for reading displacement of vibrating equipment and components. Made of fiber or plastic, it measures displacements from 0.005 to 0.3 in.

In cases where the vibration is not purely in one direction, the upright will be double lines, but in the direction of maximum displacement, these lines will be closest together.

The small dot on the device is used to determine the frequency of vibration. This is obtained from the dial of the Strobotac when it is adjusted so that the dot is stationary. It is also useful to study the

WORTHY OF

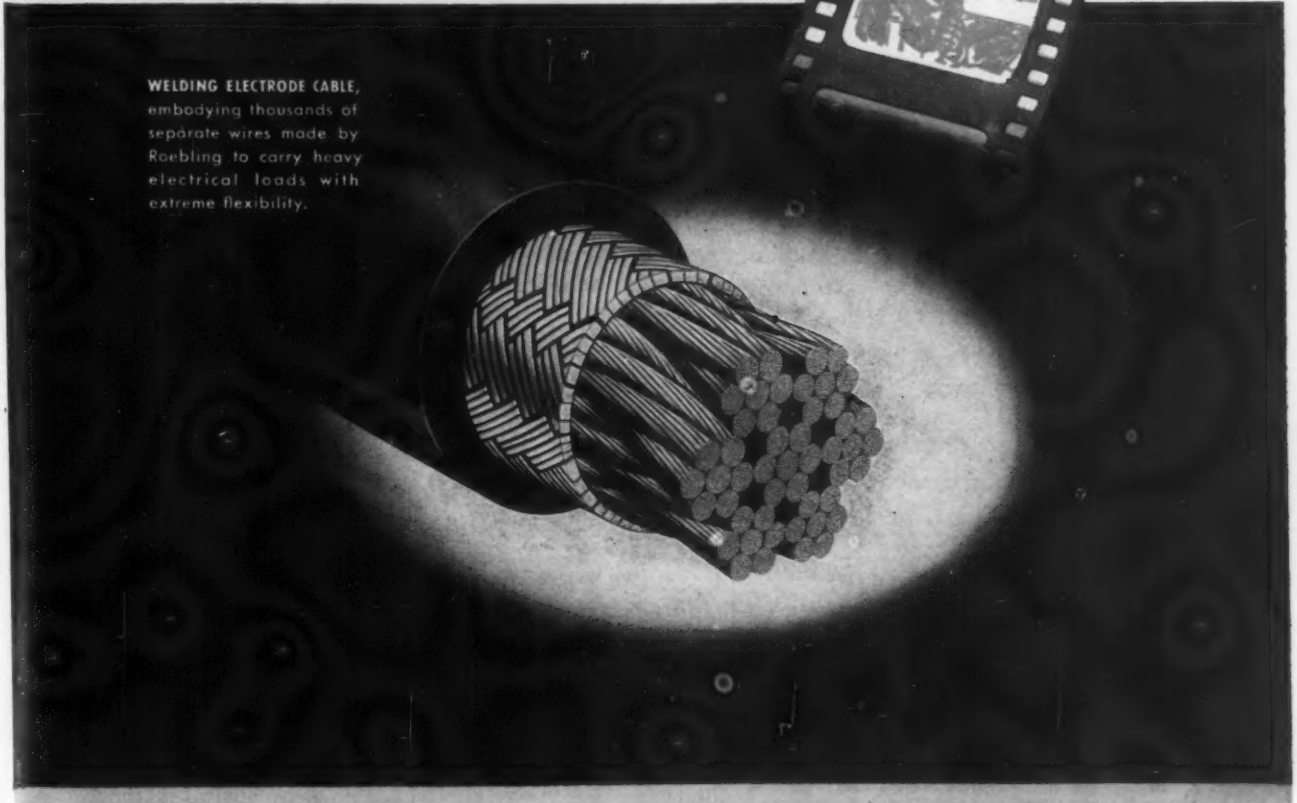
Your Own Trade Mark



The wires and cables you incorporate in your products must be every bit as dependable as the components you produce yourself. To back up our fighters today, and to back up your trade-mark in the peacetime battle of tomorrow, you can count on Roebling Electrical Wires and Cables. The conductors are drawn and stranded and laid with all the skill of years of wire specialization, Metal selection, insulation, finish are supervised with highest integrity.

You can put your trade-mark, without hesitation, on any electrical product you make in which Roebling Wires or Cables carry the loads.

JOHN A. ROEBLING'S SONS COMPANY
TRENTON 2, NEW JERSEY
Branches and Warehouses in Principal Cities



WELDING ELECTRODE CABLE, embodying thousands of separate wires made by Roebling to carry heavy electrical loads with extreme flexibility.

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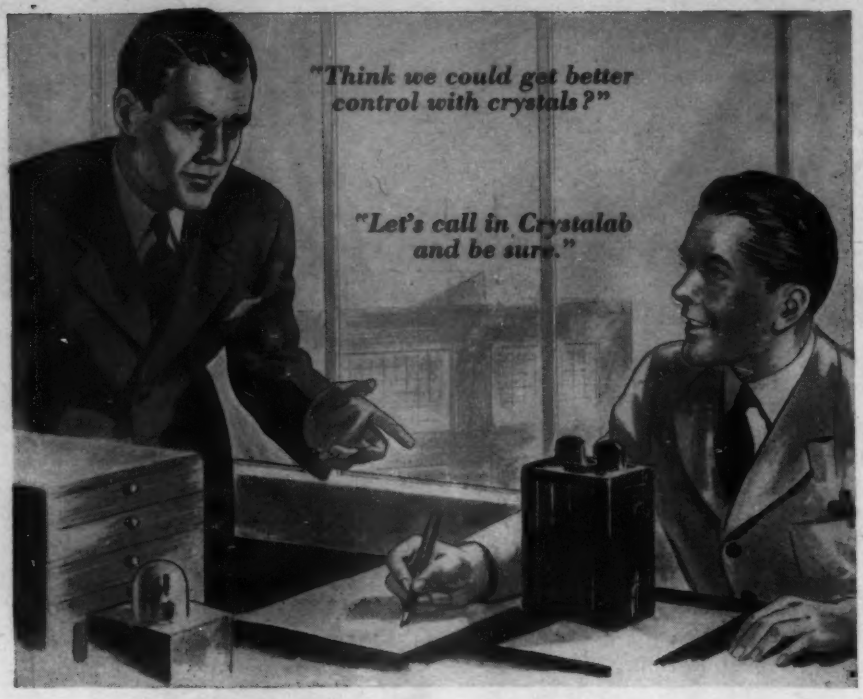
WIRE ROPE AND STRAND • FITTINGS • AERIAL WIRE ROPE SYSTEMS • COLD ROLLED STRIP • ROUND AND SHAPED WIRE
AIRCORD, SWAGED TERMINALS AND ASSEMBLIES • SUSPENSION BRIDGES AND CABLES • ELECTRICAL WIRES AND CABLES
WIRE CLOTH AND NETTING • HIGH AND LOW CARBON ACID AND BASIC OPEN HEARTH STEELS



FOR THE ANSWER to many communications problems, whether they involve crystals or not, more and more manufacturers have formed the habit of calling in Crystalab.

In the supply of crystals to rigid specifications and in their application to problems of frequency control, Crystalab has been privileged to serve the industry and the armed services many times. Government procurement specifications serve as the standard for all of industry and have been met by Crystalab from the beginning of the demand for crystals in quantity.

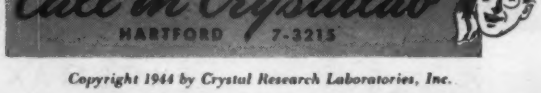
This was possible only for these reasons:

1 Crystalab engineers brought to the industry, long experience in the solution of electronic and communications problems.

2 Crystalab testing equipment includes the finest instruments money can buy, plus many special instruments designed and built in the laboratory, to meet specialized needs.

3 Crystalab manufacturing equipment, most of it specially designed and built, is capable of producing crystals in any quantity, within the narrowest frequency tolerances.

Crystalab facilities are at your service, ready to help with your current or postwar-planning problems. If experienced help in electronic research, design and manufacture is your need, you will do well to . . .



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CRYSTAL RESEARCH LABORATORIES
INCORPORATED
TWENTY-NINE ALLYN STREET, HARTFORD, CONNECTICUT

movement of the equipment while being vibrated when the Strobotac is adjusted so that the dot traces the exact path of a vibration cycle.

Displacement Scale

The device also contains a drawing of an isosceles triangle with sides $2\frac{1}{2}$ in. long on a $\frac{1}{4}$-in. base. This contains graduations 1/20 in. apart on one side to provide displacement readings in which each small division is 0.01 in.

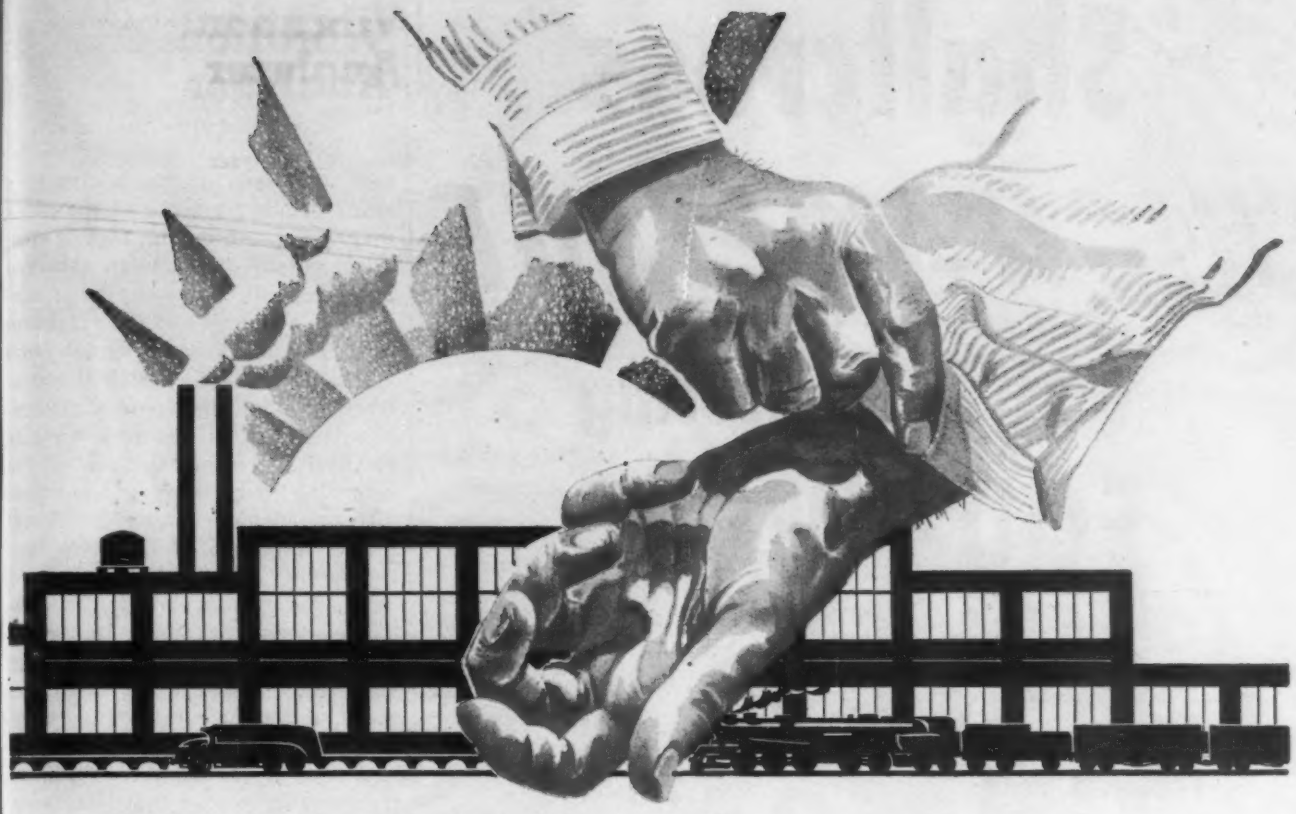
When this printed angle is observed with the Strobotac set at twice the frequency of vibration, two complete angles will be seen as shown at (*b*) of the drawing. The reading is made at the point of intersection of one graduated line with one plain line. To read maximum displacement, it is necessary to mount the gage at right angles to the direction of this displacement as obtained by the rotating disc.

From the frequency reading obtained with the dot and the displacement reading provided by the angle, it is possible to calculate the acceleration G from the formula $G = 0.0511\ df^2$, where d is the total displacement in inches and f the frequency of vibration in cycles per second.

If the frequency of vibration is known, satisfactory readings can be made with the unaided eye, as the *I* on the disc gives a blurred effect which is readily observed and read in the same manner as with the Strobotac. The angle is also blurred and the reading is taken where the two blurred lines meet. When this method is used, observations of the exact displacement can be obtained even where it is impossible for the observer or instruments to be in a steady state, as all readings depend only on the speed of light for their accuracy.

While no attempt has been made to do so, it is believed that readings of much smaller displacements could be made by reducing the dimensions of the angle by photographic means and observing the readings by optical methods.

ALMOST 200,000 persons have been trained in radio occupations since July, 1940 under the vocational training for war production program.



IT WILL SOON BE ANOTHER DAY

The lush days of "Cost Plus" that have placed so little emphasis on production economy will disappear when "C-Day" arrives. Conversion to civilian goods will again place a premium on efficiency that springs from a cost "know-how." But cost-sensitive production comes only of long experience. It is not born of wartime . . . it is a stranger to war production.

Peace-time manufacture survives only as it demonstrates the principles of profit-and-loss accounting. There is no room for carelessness, or laxity, or indifference to costs.

Lewyt is *not* a war baby. Lewyt is a "manufacturer's manufacturer" with 56 years of cost-conscious "know-how". It returns to peace-time contract manufacturing with long experience in meeting the needs of production engineers who will have only costs and efficiency in mind.

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One Contract—One Responsibility—One Cost

Lewyt's business is Contract Manufacturing. We specialize in electric and electronic instruments, chassis and housings; mechanical and electrical assemblies; highest precision machine work; sheet metal fabrications; all types of welding, product finishing, etc.

We also provide advanced engineering facilities as service assistance to our clients in connection with the design and re-design of their products under development.

Write on your business stationery for 48-page book, "Let Lewyt Do It" . . . the story of the Lewyt Organization told in pictures.

Lewyt

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HIGH-VOLTAGE
Test & Measuring
EQUIPMENT
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Percent Limit Bridges
Decibel Meters
Telephone Transmission Testing Equipment
Wheatstone Bridges
Fault-Location Bridges
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High-Voltage Measuring Apparatus
Low-Resistance Test Sets
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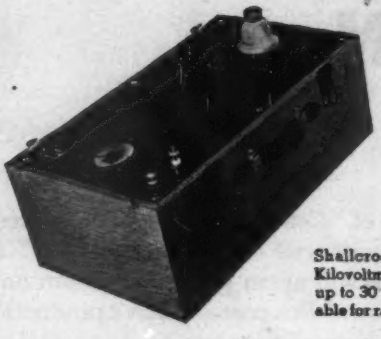
Rotary Selector Switches
Accurate Fixed Wire-Wound Resistors
Attenuation Pads
Logarithmic Decade Boxes
Portable Galvanometers



Shallcross Portable Kilovoltmeters in types up to 30 KV are available for rapid delivery.

From Kilovoltmeter Multipliers to corona-protected resistors, Shallcross offers a complete line of measuring and test equipment, as well as many components, all especially designed for the high voltages now coming into more general use. Much of this equipment cannot yet be cataloged completely. Much more is especially designed to meet customers' specifications based on the rapid advancements in radar, television, radio transmitting, dust precipitators, power transmission, and similar equipment.

Bring your high-voltage measurement problems to Shallcross!

SHALLCROSS MFG. CO.
DEPT. E-104, COLLINGDALE, PA.
ENGINEERING • DESIGNING • MANUFACTURING

Vibration Analyzer

(Continued from page 99)

the operation of the analyzer, a study should be made of the block diagram shown in Fig. 2. The electrical output of a pickup attached at some point on the engine or airplane is a function of the vibration at that point. When a signal from the pickup passes through the analyzer circuit, one frequency component out of the complex wave is rectified and moves the pen of the recording instrument in a vertical direction by an amount proportional to the amplitude of the frequency component.

The output of an electrical tachometer, which is coupled to the engine, is proportional in frequency and voltage amplitude to the engine speed. After the output of the tachometer is amplified and rectified it is caused to control the motion of the recorder pen so that it takes a specific position in the horizontal direction related to engine speed. Therefore, each curve drawn on the chart denotes the amplitude of vibration for one particular order of frequency as the engine speed varies over the entire range.

In view of the fact that the output of the pickup includes components at a number of different frequencies, it is necessary to provide a method of selecting some particular component and allowing only this one to control the action of the recorder pen. To accomplish this selection the output of the pickup is modulated by the output of an oscillator. The frequency of this oscillator is made to differ from that of the narrow-band filter by an amount equal to the component which it is desired to measure. The oscillator frequency is controlled by engine speed as indicated in Fig. 2.

To control the frequency of the modulating oscillator, a tuning capacitor is used which is operated by an electric motor. Simultaneously, this motor drives a potentiometer in a bridge circuit and for each setting of the capacitor there is a corresponding setting of the potentiometer. When this bridge circuit is in balance, no driving voltage is applied to the motor. However, when the potentiometer setting is one that does

Blue-print machine powered by a Holtzer-Cabot motor

Motor "Job Analysis" provides smooth, compact power

Experience proves that by giving advance consideration to such operating factors as torque, load cycles, starting load, reversibility, acceleration, quietness . . . then building a motor that meets the exact performance conditions . . . machines operate more efficiently and economically with less maintenance.

Since standard off-the-shelf motors cannot meet all performance requirements, the solution is a special motor . . . designed and built by Holtzer-Cabot.

For over 50 years Holtzer-Cabot has concentrated its energies in designing and building special motors to meet special operating conditions.

Today, our plant facilities are being utilized for manufacturing special fractional H.P. motors for war products, but our motor development engineers will gladly discuss your post-war fractional H.P. motor problems and requirements with you.

SPECIAL MOTORS DESIGNED TO FIT THE APPLICATION

HOLTZER-CABOT

Division of First Industrial Corporation

Designers and Builders of Special Fractional HP Motors and Electrical Apparatus

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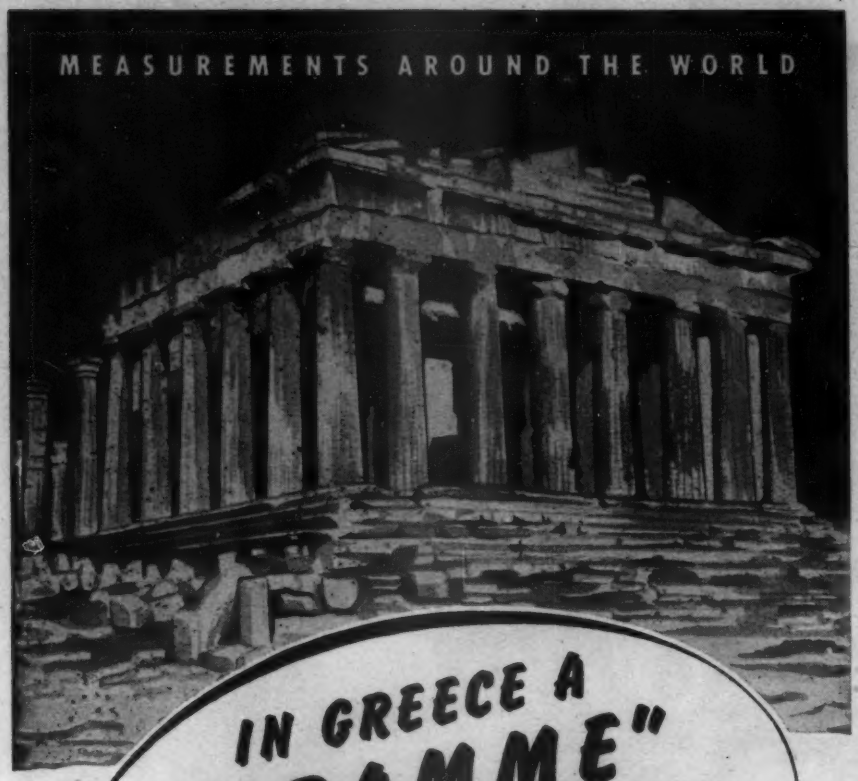


IN GREECE A "GRAMME" IS .03937 OF AN INCH

For certain types of measuring, this would appear to be accuracy in the Nth Degree.

But for the really precise and delicate calibrations required in the Radio and Electronics Fields, instruments that guarantee amazing precision must be brought into play. For many years,

MONARCH

MEASURING—TESTING—CALIBRATING EQUIPMENT has been considered outstanding in helping to produce and maintain the high standards of operation required for both war and peace.

When the requirements of war are satisfied to the degree that we can produce for peace . . . we will be ready with new ideas and new products to meet every accumulated need.

MONARCH MFG. CO.
2014 N. Major Ave. Chicago, Ill.

not balance the bridge, then the motor will be driven in such a direction as to bring about a balance.

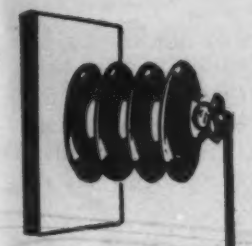
The potentiometer setting at which the bridge is balanced is different for each applied voltage and, as a result of the action of the motor when the bridge is unbalanced, both the potentiometer and tuning capacitor tend to be held at a position that corresponds to the voltage applied to the bridge circuit. The voltage applied to the circuit is the rectified tachometer voltage attenuated by a divider with 28 fixed positions. At each position the divider applies to the bridge circuit a voltage proportional to the engine speed multiplied by the selected order, and thus the K th-armonic of the motor speed.

The design of the circuit is such that the oscillator has a frequency of $(92{,}000 + f)$, where f is equal to the particular frequency component to be measured. This convenient relation is attained by designing the circuit and tuning capacitor so that the capacitor setting is made proportional to the voltage applied to the bridge circuit; as pointed out in the preceding paragraph, this voltage is proportional to motor speed multiplied by the pre-selected order, which in turn is proportional to the frequency to be checked.

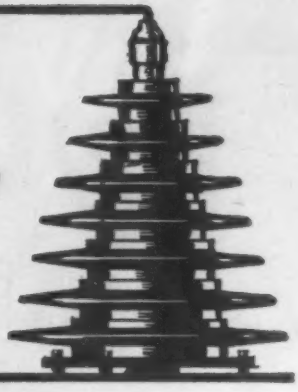
The frequency f from the amplified output of the pickup modulates the frequency $(92{,}000 + f)$ from the oscillator in the modulator circuit arranged to balance out the oscillator frequency. Thus, the two chief components in the modulator output are the sum and difference frequencies.

The output of the modulator is connected to a crystal-type filter which has a pass band at 92,000 cps that is only 4 cycles wide. By means of this filter the 92,000-cps side band is readily passed while the other side band is rejected. This signal is then mixed in the demodulator circuit with the output of the same oscillator, with the chief components of this second modulation being the carrier frequency and the upper and lower side bands. The high frequencies are easily rejected and after the frequency f is rectified it is passed to the recorder to control the position of the pen.

The main elements comprising the automatic frequency analyzer are a tachometer, small control box,



KEY to the successful development of PLASTIC products



The Ever-Lok Cord Connector with its metal collar *precision molded-in* has the strength and perfect fit necessary to meet the stringent requirements of industrial power systems.

* * *

To the designer and manufacturer of electrical products, this case history is of unusual interest because it serves as an ideal illustration of the basic formula that is the key to the successful development of all plastic products. Essentially this formula consists of (1) proper design, (2) a plastic that fits the job, and (3) *custom* molding. As one step in the development of the cord connector, this mold design was worked out (see diagram).

The groove (A) in collar (B) is extended into the plastic body (C) to form a funnel shaped groove for locking and balanced support of the plug. Holes (D) for assembling interior connections are molded at right angles to holes (E). Slight indentations are molded to mark positive and negative terminals (F). White enamel wipe-ins leave clean, sharp marks to identify terminals. Holes (G) are placed for screws which hold the connector in its shell. Rib (H) holds the connector in correct position in the shell.

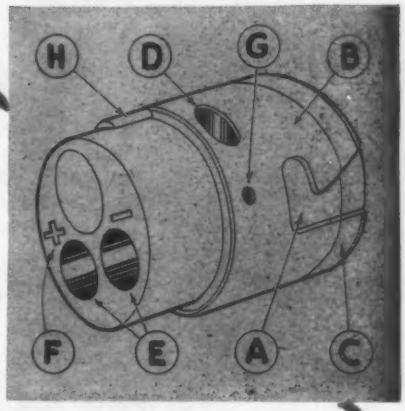
The correct choice of molding material presented an unusual problem because a *molded-in* metal collar undergoes a certain amount of expansion in the molding process and contraction upon cooling. So the plastics compound used must be capable of absorbing this expansion and contraction without cracking. In addition, it must possess all the properties required of the finished product such as

dielectric strength, resistance to impact, moisture, and heat.

From among the more than 300 versatile Durez molding compounds was selected a phenolic base material that met every requirement.

In molding this cord connector, the custom molder (American Insulator Corporation) used the transfer method —a process whereby the phenolic compound is subjected to heat and pressure and then forced into the molding cavity where it is shaped and cured. This technique was selected because it permits speedier molding and insures accurate placement of inserts.

Durez technicians and service engineers have played a big part in many of the new developments to date. This wide experience equips them to be of valuable aid. They will be glad to give their assistance at any time in helping your product designer and custom molder work out any plastics materials problem. Durez Plastics & Chemicals Inc., 810 Walck Road, N. Tonawanda, New York.



DUREZ

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PLASTICS THAT FIT THE JOB

Another "First" from the Research Laboratories of Scientific Radio

Latest development of our research engineers is the new and greatly improved 100 kilocycle crystal unit illustrated above.

This unit, Type SR3, consists of a 100 kilocycle bar, cut and ground to jewel-like precision to give a temperature coefficient of less than two parts per megacycle per degree centigrade. Metallized by a new process the crystal is rigidly clamped in a new type mounting that gives a new order of stability to the whole assembly. Designed for mounting in a standard five prong tube socket, these units are available for immediate shipment. Write today for prices and full particulars.

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Would you like to read the interesting story of the development of the American crystal industry? Send for your copy of our new brochure. It's as interesting as a tour through our plant. Yours for the asking.

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analyzer unit with the tuning capacitor drive attached to it and the recorder. Additional equipment required includes the necessary power-supply units and amplifiers for the capacitor drive unit and recorder.

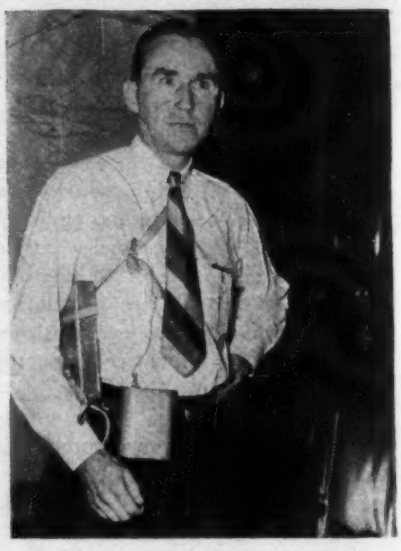
Method of Use

During a test flight, the control unit and recorder are the only parts of the equipment that require attention. On the panel of the control unit are two meters, one of which registers the amplitude of the measured signal while the other indicates the engine speed. Thus an operator may immediately observe any abnormally large vibration and the speed at which it occurs without reading the recorder. The panel is also provided with a frequency selector with which the order to be measured is selected. Also, to permit vibrations of very large amplitude to be kept within the range of the recorder and indicating meter, an attenuator is provided in the signal input circuit of the analyzer. A potentiometer which determines the voltage applied to the control device of the tuning capacitor during calibration, and four controls for calibrating the set, are also provided on the panel.

Results obtained by the use of the analyzer are being utilized by designers of aircraft engines in the gradual elimination of parts failures caused by excessive vibration.

• • •

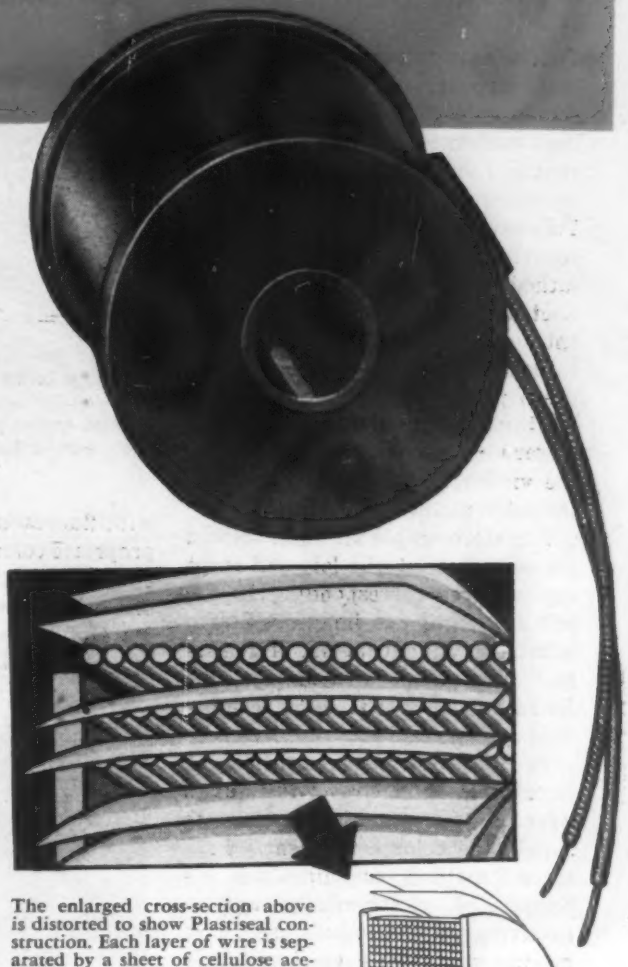
PERSONAL TRANSMITTER



A portable transmitter like those used by unlicensed operators and saboteurs was demonstrated by Charles Wilson, FCC equipment engineer, before the Lea committee investigating the FCC

Plastiseal* Coils

PREVENT CORROSION



• Anaconda Plastiseal Coils have a 12-year record of outstanding performance, which has now been highlighted by the toughest sort of war applications.

These coils are built up of sealed layers of Lumarith* (cellulose acetate) which is chemically inert under the conditions met within the coil. No paper, wax, varnish or glue is present—nor any other material which might permit electrolysis to occur and corrode the winding. The edges of the cellulose acetate are coalesced by a special process with the end washers, resulting in a complete seal. No impregnation whatever is needed.

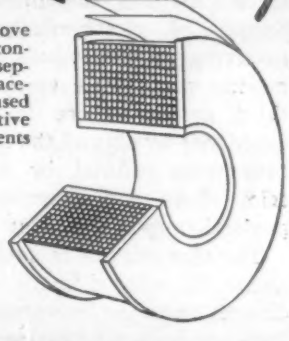
Even in the presence of moisture and direct current, Plastiseal Coils have exceptional resistance to corrosion. Appearance, mechanical strength and insulating qualities are outstanding.

Plastiseal Coils are one of the many fine *engineered* products of Anaconda. Any of our sales offices will be glad to refer inquiries to our coil engineering staff.

44256

*Reg. U. S. Pat. Off.

The enlarged cross-section above is distorted to show Plastiseal construction. Each layer of wire is separated by a sheet of cellulose acetate, the edges of which are fused to the end washers. This protective construction effectively prevents corrosion.



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TUBES AT WORK

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New Baird Tube Gives Television in Color

COLOR AND STEREOSCOPIC pictures that appear directly upon the screen of a cathode ray tube have been announced by the English inventor, John L. Baird. The system employes a new tube called the Telechrome which differs from the conventional black and white cathode-ray tube in that it has two electron beams and a transparent double-sided screen. One cathode-ray beam produces a blue-green picture on the front surface of the screen, the other a red picture on the back surface. To the viewer, the two blend to form the color picture.

For stereoscopic viewing, colored glasses are used, the left and right eye pictures corresponding to the left and right eye images. Stereo television without the use of glasses has been demonstrated by Mr. Baird but has not been made practical as yet.

In his first demonstration of color television, revolving discs were used for scanning and also to supply the color component. In a second method, scanning was accomplished electronically and a revolving color disc was used. No moving parts were employed in a third system where images produced side by side on the face of the tube were colored by stationary color filters and superimposed by projection upon a viewing screen.

The new system is entirely electronic, the colored image appearing directly upon the fluorescent screen. Two cathode-ray beams are required for a two-color system and three for a three-color system. The beams are modulated by the incoming signals corresponding to the primary color picture and impinge upon superimposed screens coated with fluorescent powders of the appropriate colors. For example, in a two-color system, the two beams scan the opposite sides of a thin plate of transparent mica one side of which has been coated with orange-red fluorescent powder and the other with blue-green fluorescent powder. The construction of this type of tube is shown at (a) in Fig. 1. Thus the screen has formed upon its front face an image containing the orange-red color components and on its back face an image containing the blue-green components, these images are superimposed to give a color picture.

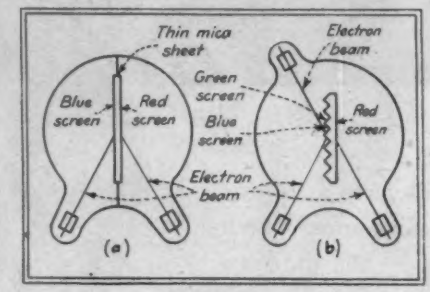


FIG. 1 (a)—Arrangement of phosphor coatings in the new television tube for a two-color system. (b) A ridged back on the screen provides two surfaces on one side of the screen for a three-color system

Three Colors

Where three colors are to be used, the back screen is ridged as shown at (b) in Fig. 1, and a third cathode-ray beam added; the front face of the screen giving the red component, one set of sides of the back ridges giving the green components, and the other sides of the ridges the blue component.

A two-sided tube has been developed that produces a picture from a 600-line, triple-interlaced moving-spot transmitter using a cathode-ray tube in combination with a revolving disc with orange-red and blue-green filters. The receiving cathode-ray tube is shown in the diagram of Fig. 1 and in the photograph of Fig. 2. The screen is a 10-in. diameter disc of thin mica coated on one side with blue-green fluorescent powder and on the other with orange-red fluorescent powder. The color may alternatively be pro-

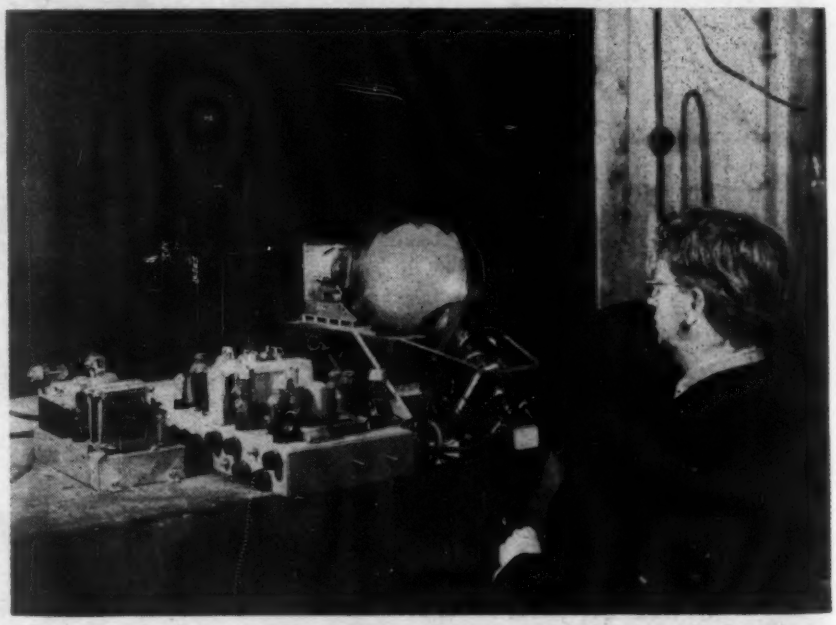
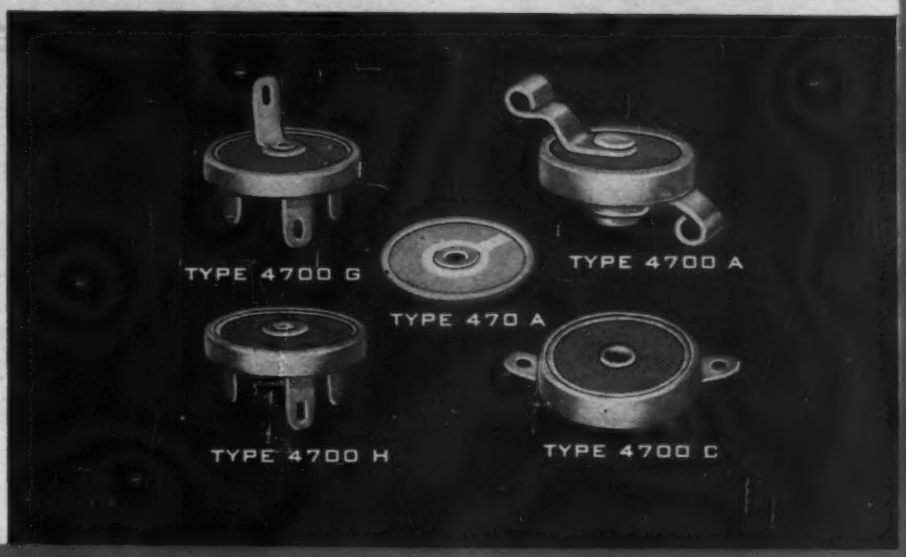


FIG. 2—Complete receiver for color and stereoscopic television with the Telechrome, a new cathode-ray tube invented by John L. Baird, noted English television engineer

Compact · Efficient · Time-Tested



Erie Button Silver Mica Condensers

THE efficiency, quality and practical application of Erie Silver Button Mica Condensers has been thoroughly proven since 1942.

These small condensers consist essentially of a stack of silvered mica sheets encased in a silver plated housing. The housing forms one terminal, the other terminal being connected to the center of the stack, thus providing the shortest possible electrical path through the capacitor.

Types 470 and 4700 have comparatively high capacity ranges and their compactness, together with the wide selection of terminal mounting designs, for by-pass applications, makes them ideal components for V.H.F. and U.H.F. applications, where short ribbon-type leads and low series inductance are prime requisites.

Capacity ranges and electrical characteristics are shown at right.

Samples will be sent to interested engineers on request.

CHARACTERISTICS

CAPACITY RANGE:
Type 470 A —100 MMF to 1000 MMF
Type 4700 A—500 MMF to 3000 MMF
Type 4700 C—500 MMF to 3000 MMF
Type 4700 G—500 MMF to 2000 MMF
Type 4700 H—500 MMF to 2000 MMF

INITIAL POWER FACTOR:
.12% Maximum @ 1 Mc. and @ 25° C.

WORKING VOLTAGE:
500 Volts DC
350 Volts AC

TEST VOLTAGE:
1000 Volts DC

INITIAL LEAKAGE RESISTANCE:
Greater than 10,000 Megohms @ 25° C.

ARMY E NAVY
FOR HIGH ACHIEVEMENT IN WAR PRODUCTION

Electronics Division

ERIE RESISTOR CORP., ERIE, PA.

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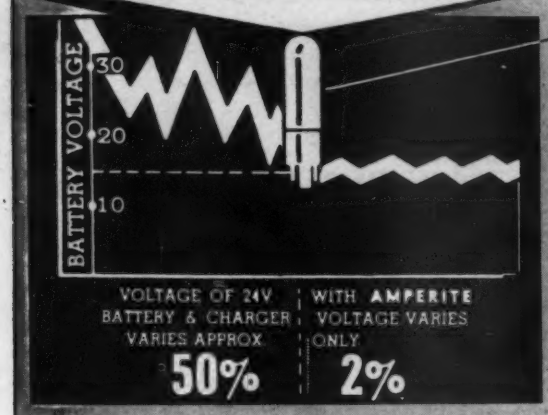
ENGINEERS: Here's the BIG POINT about

AMPERITE REGULATORS



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1. Amperites cut battery voltage fluctuation from approximately 50% to 2%.
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DELAY RELAYS: *For delays from 1 to 100 seconds. Hermetically sealed. Unaffected by altitude. . . . Send for catalogue sheet.*

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AMPERITE CO., 561 Broadway, New York (12), N. Y.

In Canada: Atlas Radio Corp., Ltd., 560 King St., W. Toronto

vided for the back screen by using a white powder and coloring the mica itself.

The tube shown in Fig. 1 (a) may be viewed from both back and front, but if used in this way one group of viewers sees a mirror image. Colored mica must not be used, and a filter is inserted between the back viewers and the tube to keep the color values correct and compensate for the light lost in the mica and fluorescent powder when the direction of viewing is reversed.

The tube shown in Fig. 2 can only be viewed from the front, but having one cathode-ray beam perpendicular to the screen simplifies the setup of the apparatus. The tubes give a very bright picture due to the absence of color filters and the fact that special powders are used giving only the desired colors which are seen additively.

The tubes give excellent stereoscopic television images when used with a stereoscopic transmitter. The blue-green and orange-red images form a stereoscopic pair when viewed through colored glasses.

John L. Baird holds his new double-beam double-phosphor coating cathode-ray tube

New Form of Scanning

In the present form of scanning, all the lines in successive frames are of the same color, the color changing with each successive frame. In the new form of scanning now being developed, successive lines are of different color and the number of lines is made a non-multiple of the number of colors, so that every line of the complete color picture has successively

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The girls who work in our plants are skilled technicians—and we can prove it. For example, the picture shown above illustrates one of the many complicated assemblies being turned out for war needs by our St. Joseph plants. The job looks difficult, and it would be except for the fact that we have a quarter of a century of experience.

Investigate and you will find that Whitaker has the "know how" and ample plant facilities to turn out cable assemblies, wiring harnesses, and flexible leads for power and lighting . . . Your inquiries are solicited. Whitaker Cable Corporation, 1307 Burlington Ave., Kansas City 16, Mo. . . . St. Joseph, Mo. . . . Philadelphia . . . Oakland.

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THE ELECTRIC AUTO-LITE COMPANY
TOLEDO, OHIO

Order No. № 6666

Req. No. PURCHASE ORDER

To Superior Graphite Products Company,
Poughkeepsie, New York.

Date January 3rd, 1920.

Ship Via F. O. B. Poughkeepsie, N.Y.

Quantity	Description	Price
1,000,000	25 - 16th Proz. Motor Brushes - Your Grade No.2 - As Per our B/P MP-17	$45.00 Per M

- Shipping Specifications -

Shipments to be made in accordance with schedule, which will be issued to you on the 1st of each month -
200,000 of the above quantity to be delivered to Willys Corporation, Poughkeepsie, New York -
800,000 of the above quantity to be delivered to Willys Corporation, Toledo, Ohio - Plant No.2.

1. Acknowledgment form attached must be filled in and returned immediately. This order and its acceptance by you are subject to the following conditions:
2. All over-shipments are made on your responsibility; we reserve the right to reject and return, at your expense, material in excess of quantity ordered.
3. The right is reserved to cancel this order if not filled within time specified herein.
4. In consideration of the purchase of the above described articles, Seller agrees to defend, protect and save harmless the Willys Corporation, and its subsidiary or affiliated companies, its or their successors, assigns, customers, and the users of its or their product, against all suits, at law or in equity, and from damages, claims, demands and judgments for actual or alleged infringements of United States or foreign letters patent by reason of the sale or use of the articles hereby purchased.

THE ELECTRIC AUTO-LITE CO.

Purchasing Agent

AFTER 25 YEARS
OUR *First* CUSTOMER
IS *Still* WITH US

1919 1944

A quarter of a century ago Superior Carbon Products began operations in Poughkeepsie, N. Y. as the Superior Graphite Products Company. Our "first customer" was The Electric Auto-Lite Company of Toledo . . . It is a pleasure to be serving Auto-Lite still. We like to think that perhaps Superior Carbon Brushes have contributed something to the excellence of the Electric Auto-Lite product.

No, we're not going to deliver a lecture on the value of quality in keeping customers on one's list. Certainly we will exert every effort to maintain the quality of Superior Carbon Brushes . . . Nor on the importance of service and deliveries. However, we promise you our utmost in this respect despite the present difficult conditions with which we all have to contend. We will endeavor to make Superior service worthy of a place in every customer's picture.

SUPERIOR CARBON PRODUCTS, INC.
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"Since 1919" SUPERIOR CARBON BRUSHES

shown each of the primary colors.

The object of this is to reduce color flicker. Where frame by frame color alteration is used, flicker becomes prominent in any large area of a single color, for example, if the picture is showing a large blue area, this blue appears in the blue frame only. While the red and green frames are appearing, it is not shown, so that the frequency of the repetition is reduced and flicker accentuated. With line by line color alteration, each color appears in every frame. This form of scanning does not lend itself to the revolving disc system.

• • •

Routing Cabs by Radio

A PLAN PROPOSED by Cab Research Bureau, Inc., representing the taxi industry, and the Electronic Department of General Electric Co., would make it possible to establish contact by radio with any cab at any place in Cleveland, reduce cruising mileage and eliminate unattended call boxes connected to telephone lines. If approval can be obtained from the FCC, this would be the first two-way taxicab radio system in the country.

The plan calls for one main transmitter for the downtown area and two others to cover the rest of the city. Each transmitter would have four channels, with 100 cabs assigned to each channel.

That radio-equipped cabs might be very useful in emergencies growing out of fire, crime, and accidents was pointed out by D. L. Chesnut, G-E commercial engineer. He pointed out that, "the taxicab industry in each major city might draw up an agreement with that city permitting the police department to commandeer its radio cars and its headquarters station at any time that a major public disturbance should warrant."

• • •

Robot Radio Stations Forecast Weather

AUTOMATIC WEATHER stations in secret locations from the arctic to the tropics are playing a major role in coordinating allied land, sea and air attacks with favorable weather. The robot weather bureaus were de-

Yesterday and TODAY

The Army-Navy Production Award for outstanding achievement in producing vitally important materials essential to the war effort will be an added incentive to the management and employees of **WARD PRODUCTS CORPORATION** to keep producing more and better equipment for the men who are doing the fighting. While yesterday **WARD** Antennas were accessories for pleasure, today they are implements of War.

WARD *Antennas*

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Date January 3rd, 1920.

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Quantity	Description	Price
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	- Shipping Specifications - Shipments to be made in accordance with schedule, which will be issued to you on the 1st of each month - 200,000 of the above quantity to be delivered to Willys Corporation, Poughkeepsie, New York - 800,000 of the above quantity to be delivered to Willys Corporation, Toledo, Ohio - Plant No.2.	

1. Acknowledgment form attached must be filled in and returned immediately. This order and its acceptance by you are subject to the following conditions:
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veloped and placed in production by Friez Instrument Div. of Bendix Aviation Corp. within a year after the Navy requested the devices.

The Navy wanted a device which would report automatically on weather conditions by radio from remote points back to official weather control locations, and while Friez engineers already had the necessary meterological instruments they had to start more or less from scratch on equipment for power and timing of automatic radio devices necessary to broadcast reports and data continuously gathered by recording instruments. Weather and termite-proof insulated houses were developed to shelter the recording and radio instruments. Since weather in the English Channel originates around Greenland, it was necessary to build the automatic stations able to withstand the severe arctic climate of that region. For the most part, the stations require servicing only at intervals of several months.

• • •

Electronic Operation of a Standard Stop-Watch

By R. J. Wey and J. H. Jupe
Middlesex, England

In using a stop-watch over intervals of one minute or less the error, due to human causes, may be appreciable and the following description deals with apparatus designed to overcome this. A phototube is used so that the mechanism being timed is physically separate from the timing apparatus, with the result that mutual interference is nil.

The light beam can be interrupted or modulated in various ways but to reduce circuit errors to a minimum the best method is to operate the relay in the same direction at both ends of the cycle. The inherent time delays will then cancel out. This device has been in use for a long time and has been found to be extremely reliable and convenient for laboratory work.

Four basic modes of operation are possible, as follows:

1. Double occultation;
2. Double illumination;
3. Single occultation;
4. Single illumination.

A schematic of the circuit for the

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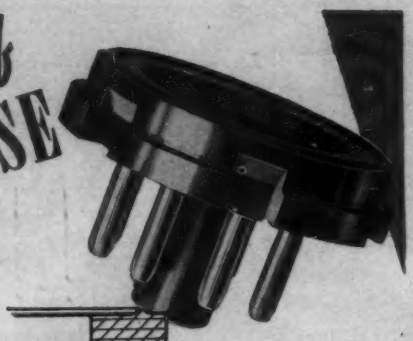

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most useful (double occultation) is given in Fig. 1.

The phototube is coupled to the grid of the amplifier tube by resistor R_1 and capacitor C_1, while in the anode circuit is an ordinary telephone-type relay. Double-pole double-throw contacts are provided on this and its operation is indicated by the signal lamp L_1 being supplied via contacts 5 and 6. Grid bias of the tube is adjusted by potentiometer R_2 until sufficient anode current flows to give positive operation

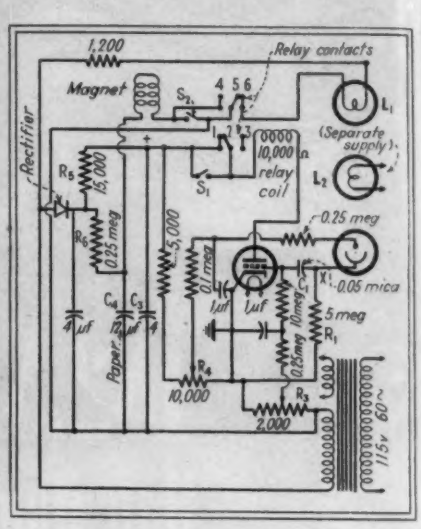

Fig. 1—Circuit for starting and stopping a stop-watch by two interruptions of a lightbeam. Lamp L_1 is a 230-volt, 15-watt bulb

of the relay (approximately 3.5 to 4 ma.). The phototube anode potential is adjusted by means of resistance R_4, both anode supplies being obtained from the metal rectifier and smoothed by capacitor C_3 in conjunction with resistor R_5.

Operation

Normally, the phototube is illuminated, so that point X is positive with respect to the cathode of the amplifier tube. Interruption of the beam causes the grid potential to fall to a low value and the relay releases when the anode current changes. Three things then happen:

The watch is started by the electromagnet being energized; the signal lamp is no longer illuminated; the anode circuit of the amplifier tube is opened.

This last is useful as the amplifier is rendered proof against control by the phototube while timing is in progress. Near the end of the timed

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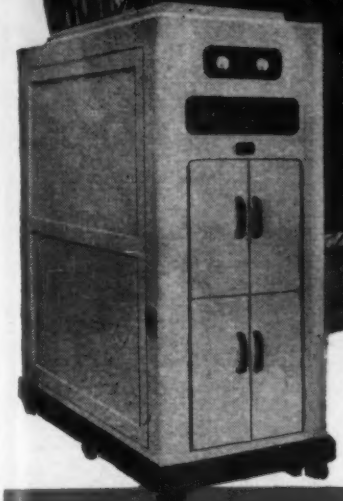

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cycle, pushbutton S_1 must be operated to reconnect the amplifier by allowing anode current to pass and pull in the relay armature. After this, the first occultation will energize the magnet and stop the watch. Switch S_2 resets the watch to zero.

Referring to the schematic, it will be seen that the current for operating the magnet is obtained from capacitor C_4, which is charged to some 300 volts through resistor R_6 and discharged through the magnet coils when contact 5 closes onto 4. Although the magnet requires some 50 ma. for its operation, the rectifier load is only increased by about 1.5 ma., and as the discharge is comparatively heavy and of short duration, the operation of the device is quick and positive.

Sometimes it is neither desirable nor possible to achieve double occultation of the phototube, in which case a flash of light from a moving mirror may be used to start and stop the watch. The circuit must then be revised as follows: 1. Interchange the positions of the phototube and the resistance R_1; 2. Vary the amplifier tube bias so that the anode current is normally zero and change over the connections to 4 and 6 of the relay. Contacts 1, 2 and 3, also reset button S_1, will be cut out of the circuit.

Single Illumination or Occultation

When operation by single illumination or occultation is required,

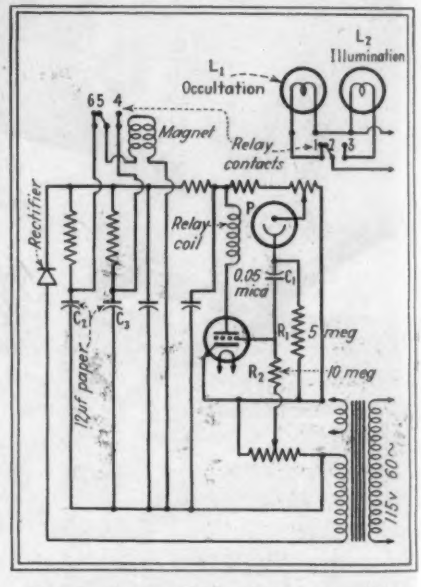
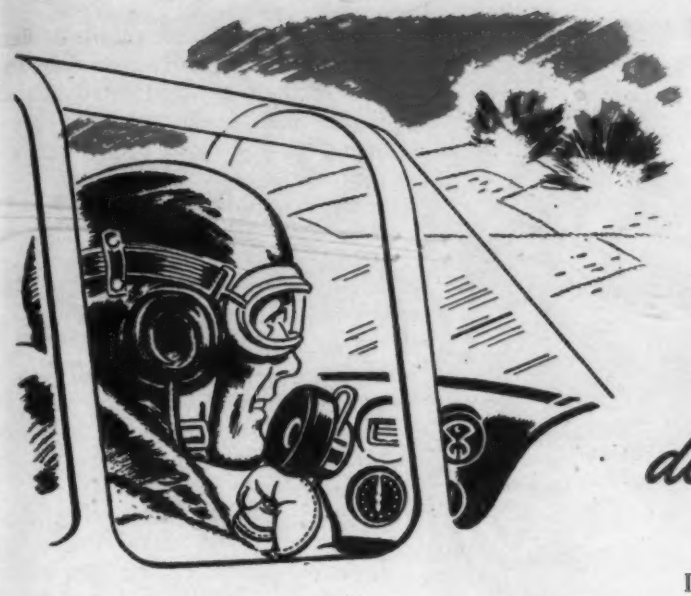


Fig. 2—Single illumination or occultation will operate the circuit above. Except as shown, constants of components are the same as Fig. 1



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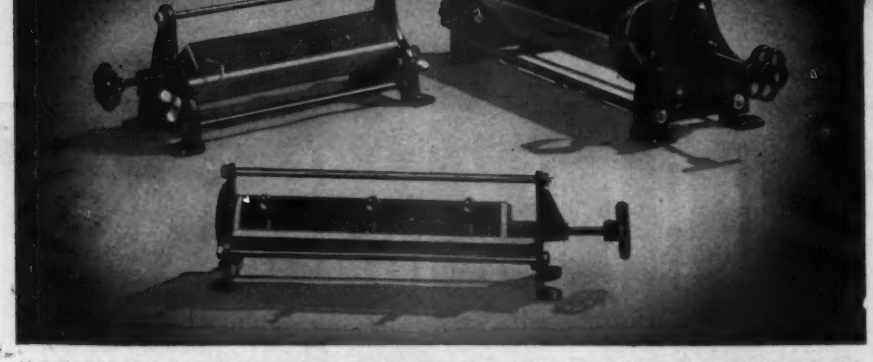

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the simplified circuit shown in Fig. 2 may be used, in which case the bias of the tube is adjusted so that its normal anode current corresponds to the mean operating current of the relay.

Upon occultation, the relay will drop out, causing C_4 in Fig. 2 to discharge through the magnet winding and so start the watch. While the phototube is in darkness, the anode current will slowly rise (the time being determined by the time constant of R_1, R_2, C_3) but will not operate the relay owing to its pull-up current being different from the drop-out value.

When the phototube is illuminated at the end of the cycle, the anode current will rise still further and the relay will operate and energize the electromagnet from capacitor C_4. A little later the anode current will return to its original value but the relay will still hold in. The circuit is then ready to respond to a further occultation of the beam.

Modes of operation 3 or 4 are made possible by checking that the relay is in the correct condition before the timing cycle commences.

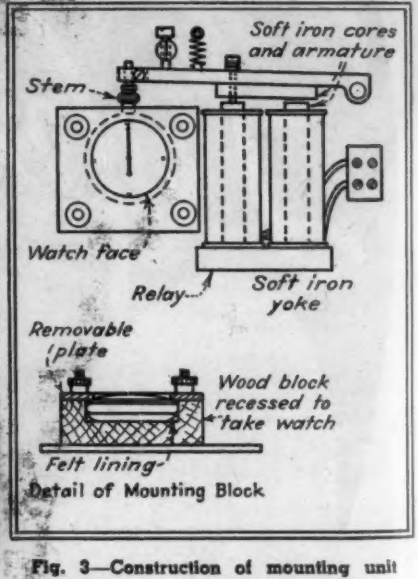
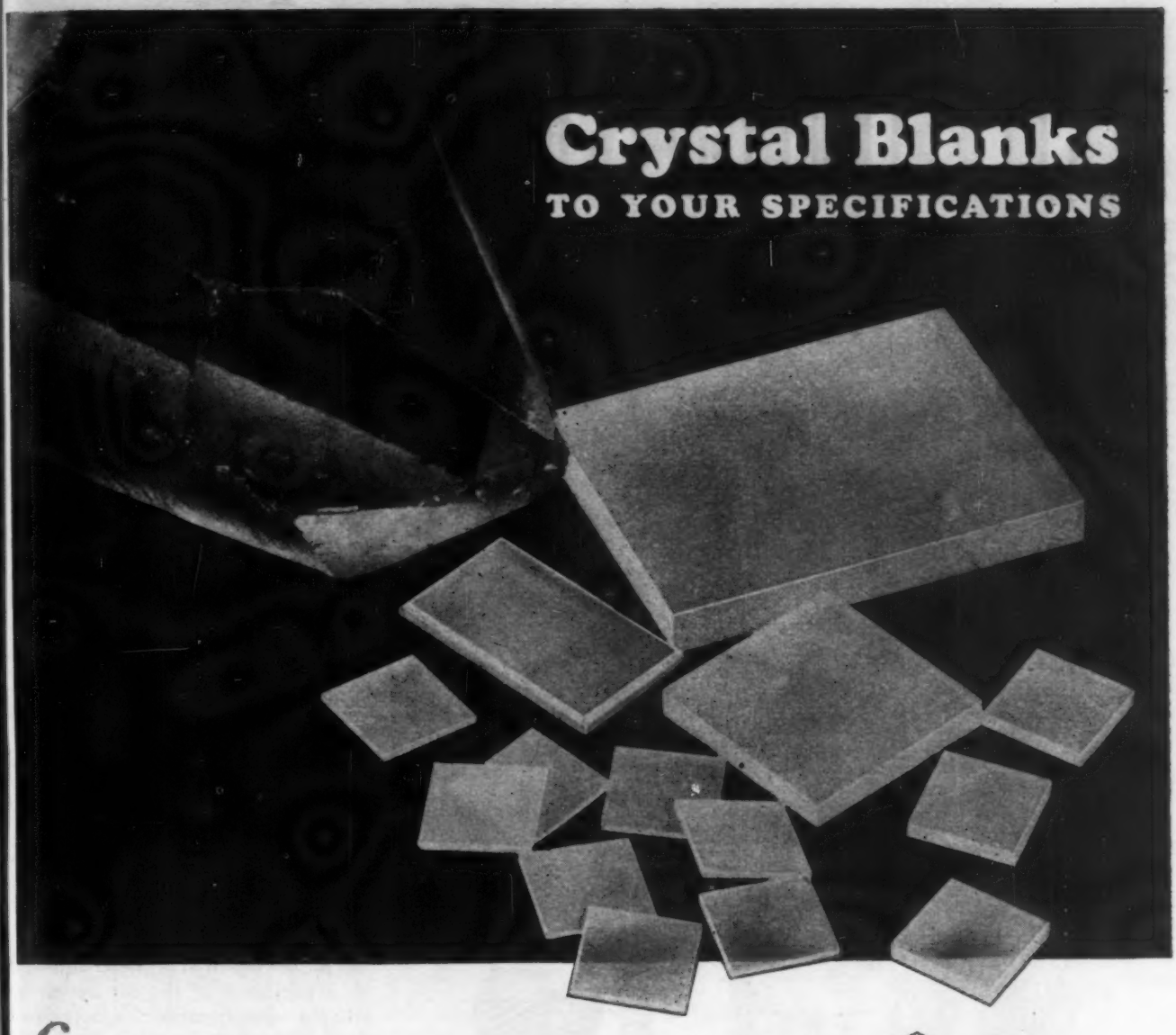


Fig. 3—Construction of mounting unit for adapting a standard stop-watch to an electronic starter

The signal lamps L_1 and L_2 may be marked to show whether occultation or illumination is required to operate the apparatus. As there are two capacitors, C_3 and C_5, in use, the watch must be reset to zero by hand, otherwise two reset buttons are necessary.

The general arrangement of the



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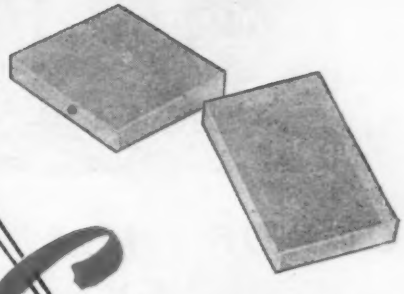

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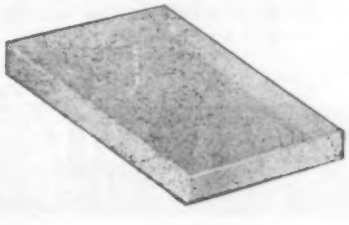

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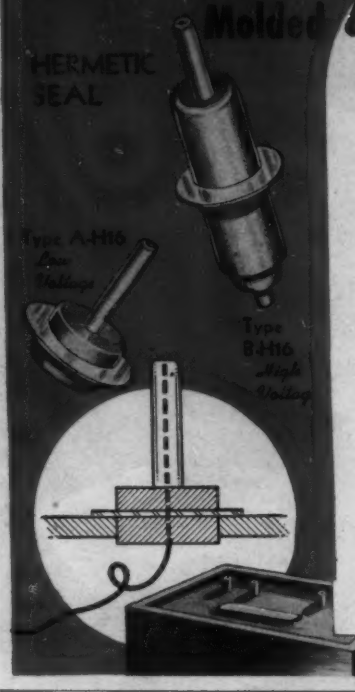

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watch unit is given in Fig. 3. Clamping nuts hold the watch in position and a felt pad prevents damage.

The electro-magnet coils are 3½ in. long by 1¼ in. in diameter and are wound with No. 36 B and S enamelled copper wire, about 12,000 turns being necessary. A diameter of ⅝ in. is adequate for the cores while a minimum air gap of 0.02 in. is satisfactory between armature and pole face.

It should be noted that the screw which projects through the armature to the pole face must touch the latter before the knob of the watch is fully depressed, otherwise considerable force may be exerted on the watch mechanism. Thanks are due the Editor of *Electronic Engineering* for permission to reproduce certain copyright material.

• • •

Substitute for Car Antenna Checks Capacitance

By PAUL F. MAGEE
Cross Roads Auto Service, Berlin, Md.

DUE TO THE SHORTAGE of manpower, we have not been able to actually remove or reinstall any car radios, nor make any adjustments on the set in the car. However, we have been repairing them to a great extent on the bench after determining the capacitance of the car antenna with a simply-made capacitance bridge. This instrument enables the serviceman to line up the radio at the test bench under the same conditions as the set encounters when installed in the car.

A reading is obtained by connecting the bridge unit to the car antenna with the antenna lead disconnected from the car radio set. The unit is then carried in to the service bench and plugged into the auto radio for the alignment procedure and a switch is set to connect the proper capacitance into the receiver input circuit. The time required to take the bridge reading is practically nil and by recording this reading the set can be aligned properly without the car antenna at some later date.

As illustrated in the diagram, the device is a bridge circuit using two resistors on one side of the bridge and two capacitors on the other side. One of these is a known

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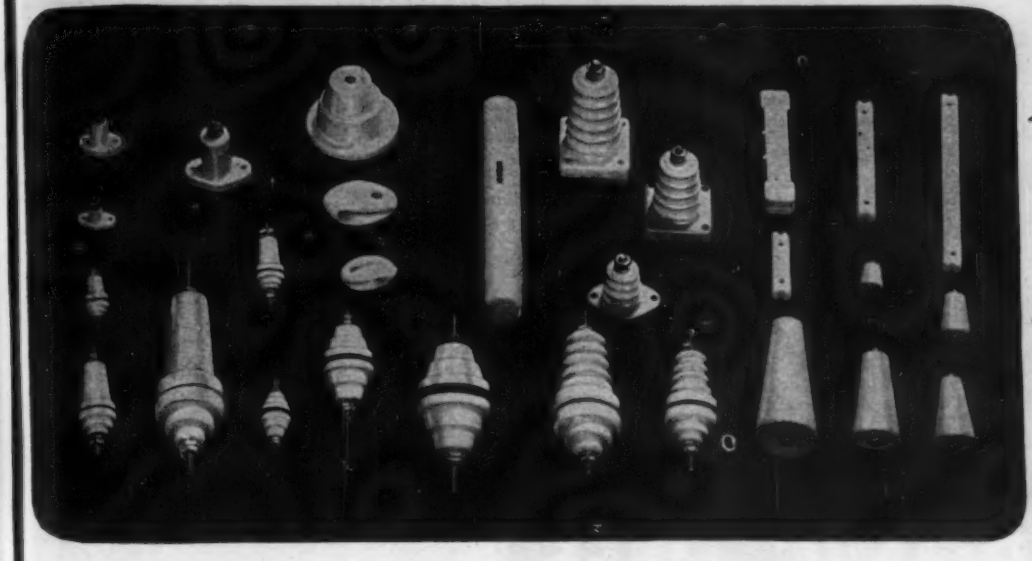

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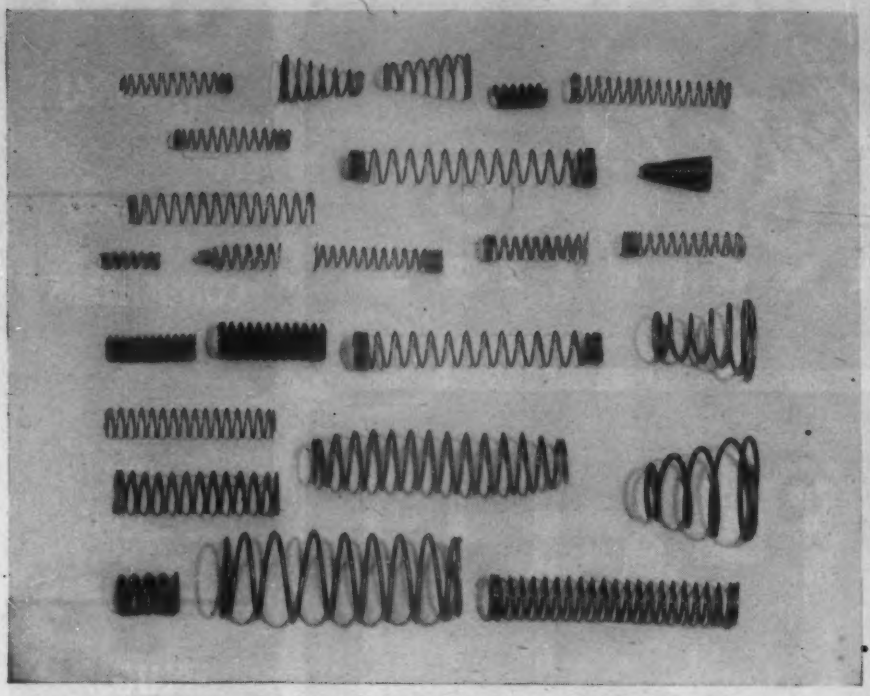

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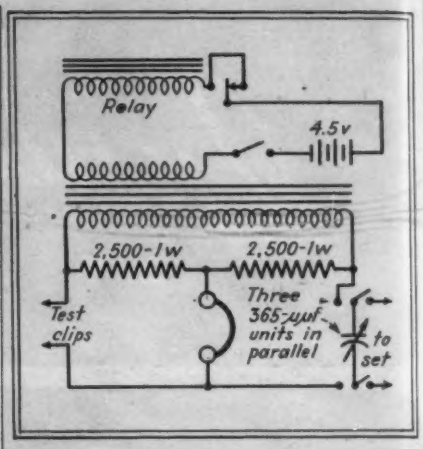

Bridge circuit for measuring the capacitance of a car antenna. The unit acts as electrical substitute for the antenna when it is necessary to align the receiver on the bench. Plug-in antenna adapters permit quick checks

capacitance and the other unknown. When connected as shown, the relay furnishes the buzzing sound to provide an audible sound for balancing the known capacitance to the unknown capacitance of the antenna circuit in the car.

The transformer is a line-to-voice-coil type. The voice-coil winding is connected in series with the relay, battery and switch.

Three flashlight batteries have lasted for a long time. The layout of the components is not critical and all of the parts were installed in a box 6 x 9 x 4 in. The dial is mounted on one end and was calibrated with the aid of a capacitance meter used in normal service work.

The device has sufficient antenna effect to permit operation of the set

Dial Reading	Cap. in μμf
0	100
20	160
40	300
60	550
80	900
100	1250

without an additional antenna connected if the set is operating properly. By using the unit on every set, a sense of judgment can be obtained as to whether the repaired set is satisfactory. The set is aligned for greatest sensitivity from one end of the band to the other, even if the oscillator trimmer capacitor has to be varied slightly to obtain satisfactory results.

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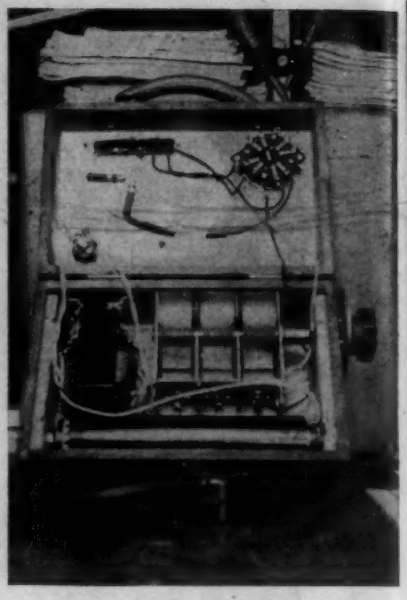

With components mounted in a wooden box, the capacitance bridge can be carried to the car to check the antenna and back to the bench for substitution of the correct capacitance

almost any installation using side-of-car antennas. A 500-$\mu\mu$f capacitor may be connected temporarily to facilitate testing an under-car antenna. This temporary connection can be made across the gang inside the box.

The unit can also be used for regular checking of capacitance, but is of little value where voltage must be applied in the checking process. The dial scale can be elaborated to any extent, but the values given below were sufficient for our purpose.

• • •

Skyhook for Gibson Girl

THE 300-FT ANTENNA used with the Gibson Girl emergency transmitter (shown on the cover of the September, 1943 issue of ELECTRONICS) is supported by a yellow kite made of steel and cambric. Combined with the transmitter, the kite is standard equipment in rubber life rafts on all bomber and transport planes.

The framework of the kite is formed of stainless steel tubing that is first passivated to remove all foreign matter from the metal and is then put through a 200-hour salt-spray test to provide a standard of resistance to the climatic conditions which may later be en-

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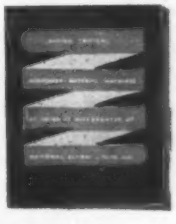

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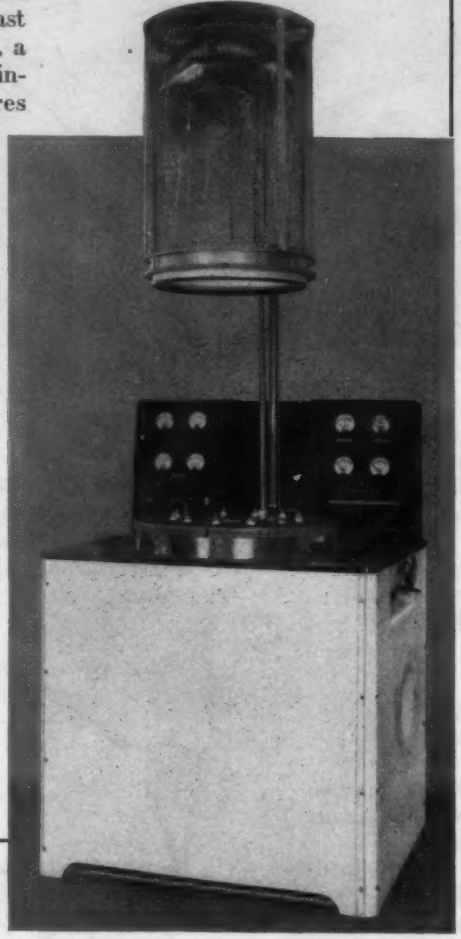

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countered in the various war zones. Small corks are inserted in the open ends of the tubing to render them watertight.

The skirts of the kite are made of a water-repellent cambric that has a tensile strength of 39.4 on the warp and are given buoyancy by corner paddings of kapok. Cold-rolled steel clamps which have also been given the corrosion tests hold the skirts to the frame.

A product of Hoffman Radio Corp. of Los Angeles, Calif., the kite can ride out a wind of 50 miles per hour and permits the transmitter to cover a range of 300 square miles in average weather. The kite stands 36 in. high when open and weighs but 12½ oz.

• • •

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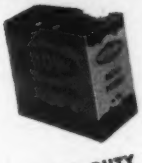
PORTABLE "A"



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Open-Grid Tubes

(*Continued from page 128*)

no case did omission of the grid leak lead to excessively high plate current or to high operating temperatures, nor did the grid bias become high enough to block the tube. In the ageing test, open-grid tubes also performed better than tubes with a grid leak. The noise is also less with a cathode resistor (of proper size) than without one. With a fixed bias resistor and variable plate voltage the least noise was obtained with a plate voltage of about 90 volts for a 6SJ7 tube.

Conclusions

If the tubes are to be operated with nearly zero grid bias the lower noise level obtained by the omission of the grid leak is especially noticeable. From Table 1 it can be seen that for optimum grid bias the ratio of noise with a grid leak to the noise without a grid leak is 1.11, and for zero bias this same ratio is 1.97. This shows the advantage of operating without a grid leak for zero bias.

Operation of a tube without a grid leak seems practical in applications involving low-level operation, with no d-c potentials in the preceding stage, and a negative grid bias of not more than about 2 volts.

Tests were also performed on pentode-connected 6SJ7 tubes and on 6J5 tubes, and similar results were obtained.

References

(1) Reich, H. J., "Theory and Applications of Electron Tubes," McGraw-Hill Book Company, 1939, p. 184.
(2) Everitt, W. L., "Communications Engineering," McGraw-Hill Book Co., 1937, p. 241.
(3) Harris, W. A., Fluctuations in Vacuum Tube Amplifiers and Input Systems, *R. C. A. Review*, 5, April 1941, p. 505.

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(1) King, Ronald, A Screen Grid Voltmeter Without External Leak, *Proc. I.R.E.*, 22, June 1934, p. 771.
(2) Moullin, E. B., "Spontaneous Fluctuations of Voltage," Oxford Univ. Press, 1938.
(3) Terman, F. E., "Radio Engineering," McGraw-Hill Book Co., 1937, p. 228.

GIRL POLICE RADIO OPERATORS, Ruth Boddy and Jean Pinnell, are employed by the Missouri State Patrol. They have been working at the net control station in Jefferson City.

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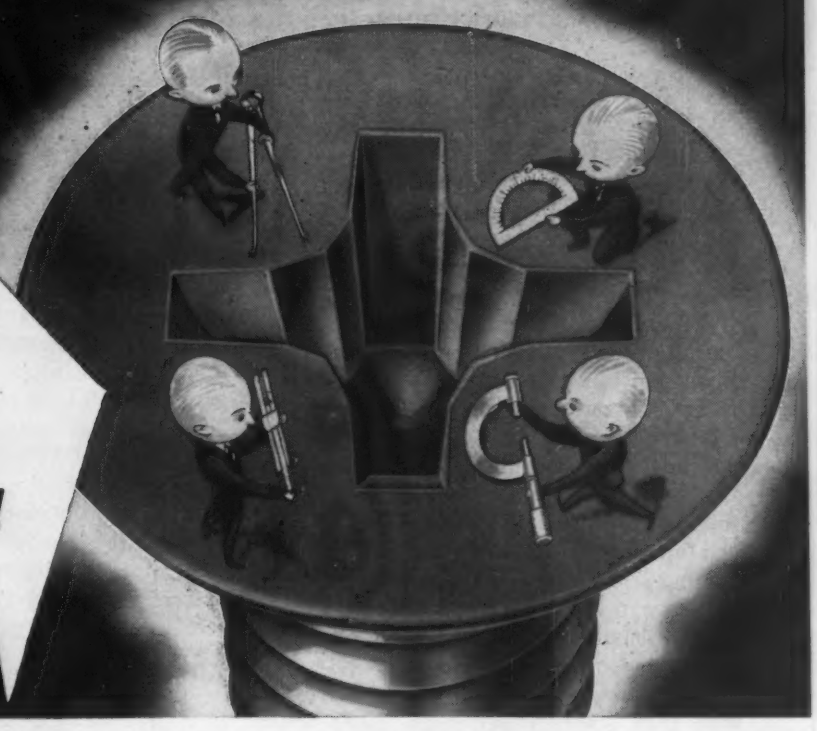

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THE ELECTRON ART

Grid-Current Characteristics of Typical Tubes 236
Electronarcosis Therapy 252

Grid-Current Characteristics of Typical Tubes

By LOWELL W. ZABEL
Radio Engineer
Wilcox Electric Co.

DURING THE PAST few years, considerable interest has been shown in the applications of vacuum tubes to such problems as the measurement of direct voltage and current. In particular, tubes have been used in stabilized vacuum-tube voltmeter circuits which have sufficiently high input resistances that little effect is had on the measured circuit. Likewise, vacuum-tube microammeters and micro- microammeters such as that of A. W. Vance* require high input resistances. These problems are the same as those met when designing a phototube amplifier where the tube must react to very low light intensities.

The obvious method of obtaining high input resistance combined with high stability is to use specially designed low grid-current tubes in a balanced degenerative circuit. However, in many instances the relatively high cost of such tubes and the lack of necessity of the use of extremely high values of input resistance make it desirable to seek some more readily available and less expensive tube. Since data concerning the grid current characteristics in the negative grid region is not available for the more common tubes, it is the purpose of this article to give some data on a few receiving type vacuum tubes.

The measurement of the minute currents that flow in the grid circuit of a negative-grid, direct-current amplifier must be done indirectly unless a very sensitive galvanometer is available, and even then the grid current of the best of the receiving-type tubes can not be measured. The indirect method which was used to obtain the data given here can be made fully as accurate. The circuit shown in Fig. 1 is used.

Method

The procedure is first to run the grid-voltage vs plate-current curve for the tube in question, using the same values of plate, screen (if a pentode) and heater voltage under which it is desired to operate. At a given value of E_c, the plate current is read on M_2 with S both open and closed. The difference in plate current with and without R_g in the circuit can be converted to a change in grid voltage from the static curve previously plotted. The grid current is determined by dividing the change in grid voltage by the grid resistance R_g.

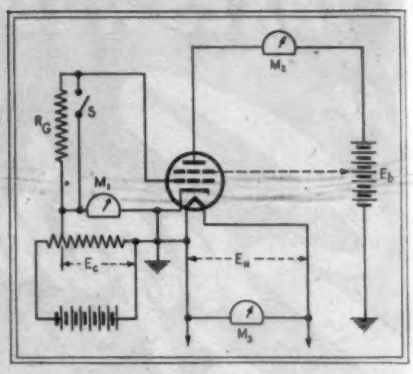

Fig. 1—Circuit used in obtaining data for curves of grid-current characteristics by the indirect method

The accuracy of the method depends on the accuracy of the plate current and grid bias meters and the accuracy to which the grid resistance is known. The overall accuracy can quite readily be kept within ±15 percent.

The tube types selected for measurement are all readily available and are considered representative types. The curves of Fig. 2 show the grid current I_g that may be expected from an average 6J5 triode. These curves show that some improvement can be obtained by lowering the heater voltage below the

* Vance, A. W., *Rev. Sci. Inst.*, 7, 489, 1936.

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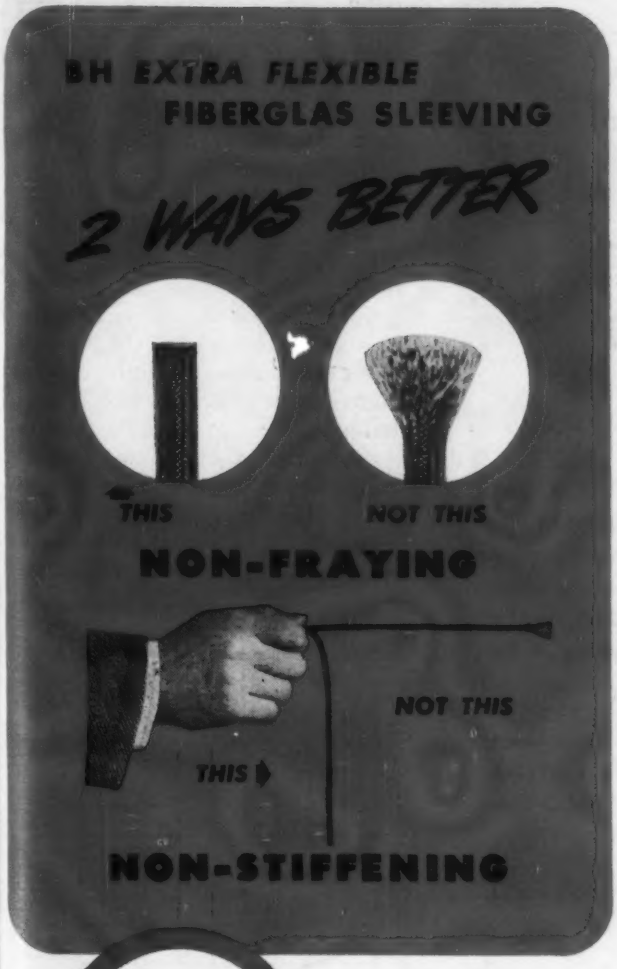

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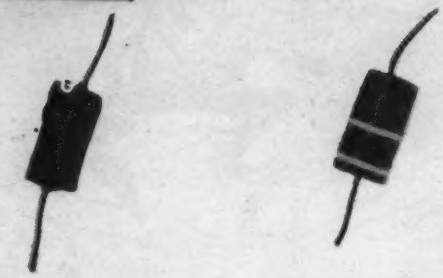

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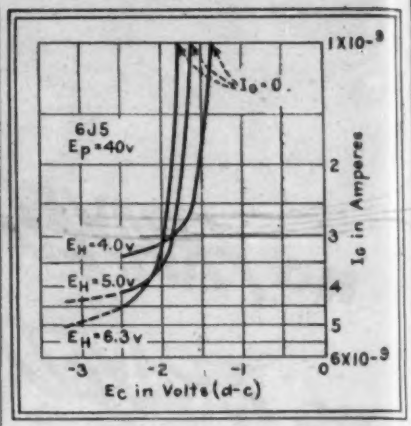


Fig. 2—Grid-current curves of a 6J5 tube with 40 volts applied to the plate

rated 6.3 volts. It is probable that decreasing the voltage below 4.0 volts would result in still more reduction of grid current, but at such a low heater temperature that plate-current saturation is easily reached. Operation of a tube near the maximum emission results in instability, therefore it is advisable not to reduce the heater temperature too far.

Need for Low Voltage

Figure 3 is a similar set of curves for a 6SJ7GT connected as a pentode. Here the variable parameter is plate and screen grid voltage. The curves make it quite obvious that for low grid current it is to a decided advantage that the highest voltage present within the tube envelope be not much greater than 40 volts. Higher voltages than this cause slight ionization of the minute amounts of gas remaining

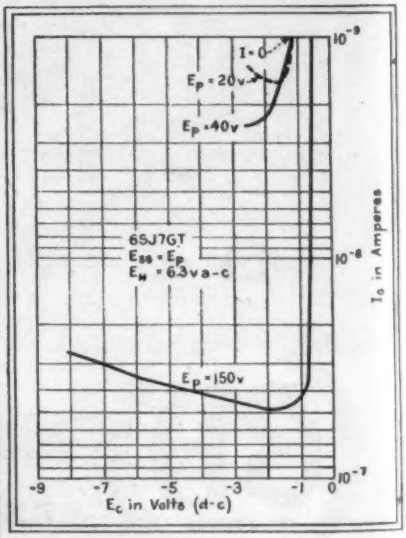
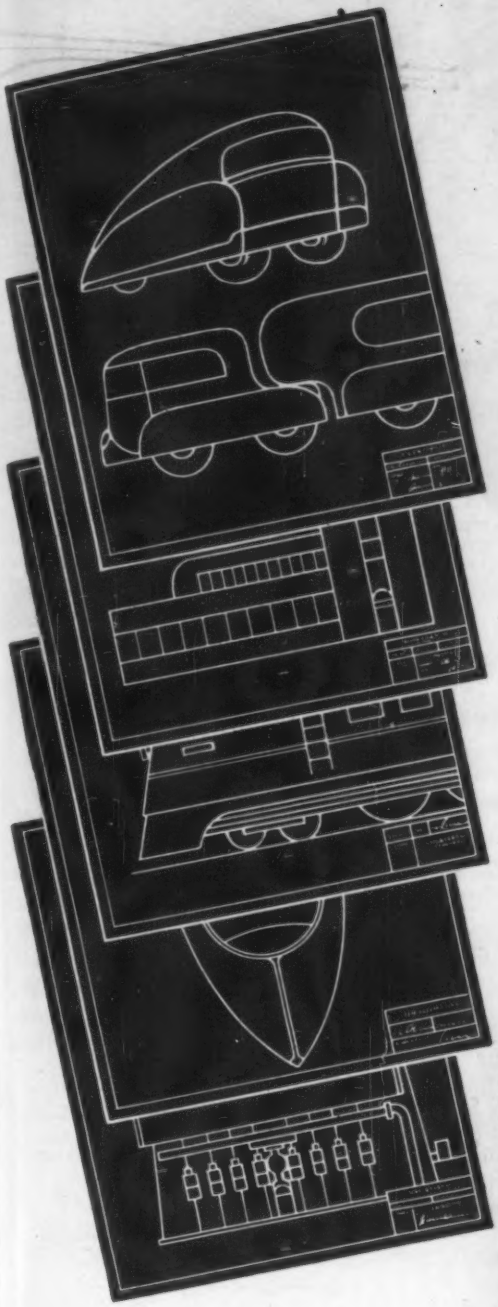


Fig. 3—Grid-current curves for a 6SJ7GT connected as a pentode

SPEED-UP



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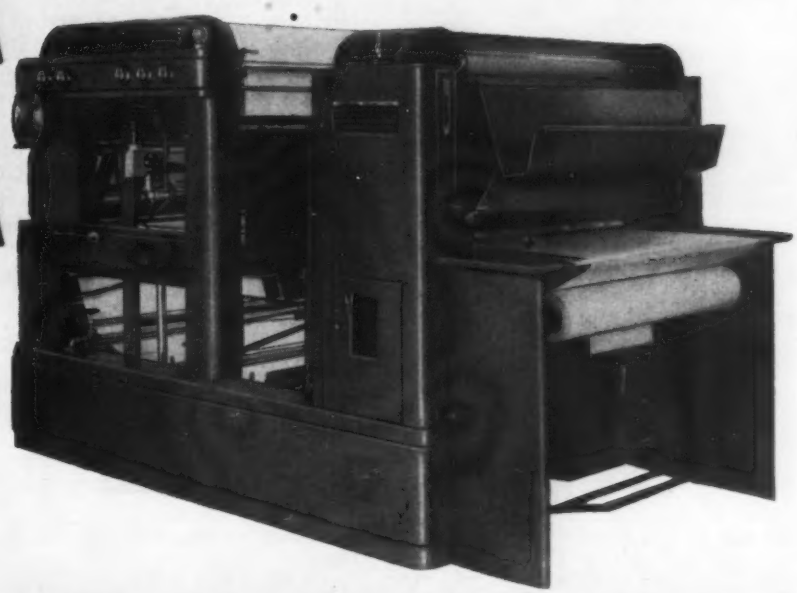

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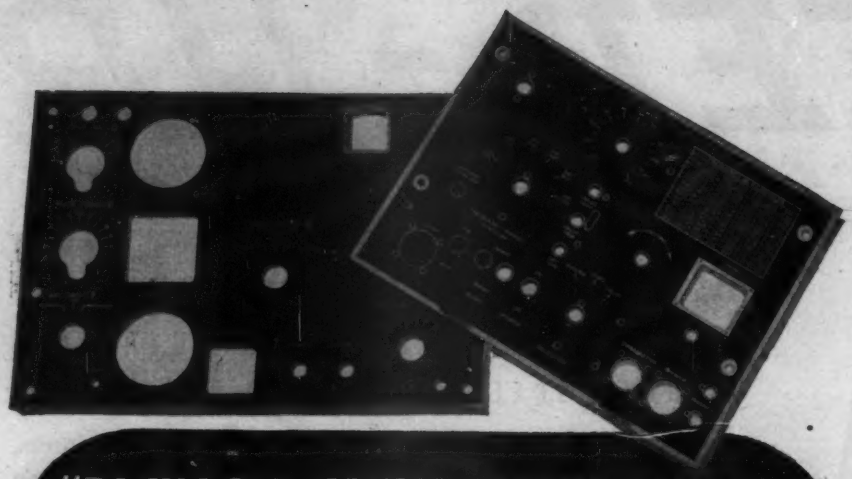

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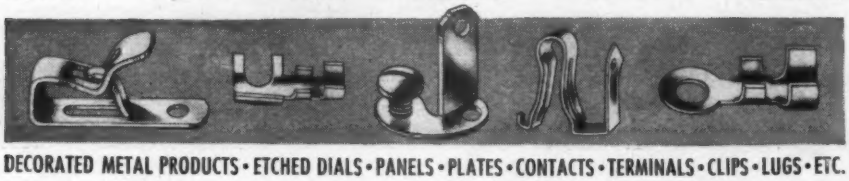

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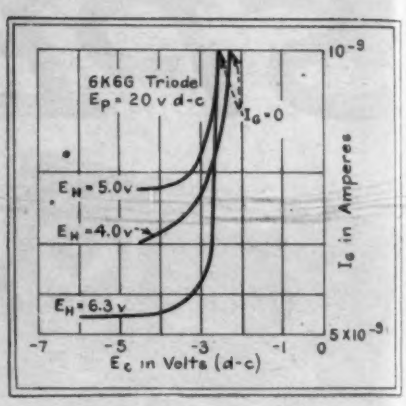

Fig. 4—Effect of reduced heater voltage on grid current of 6K6G connected as a triode

within the tube after gettering. Positive ions migrate to the grid, thus causing the relatively large current shown at $E_P = 150$ volts.

Figure 4 is similar to Fig. 2 except that the curves are of a 6K6G connected as a triode. An advantage of almost two to one is obtained by operating the tube at reduced heater voltage.

Figure 5 shows the effect on the grid-voltage vs plate-current characteristic of a 6V6GT triode with increasing values of grid-circuit resistance. As the grid circuit resistance is increased beyond the values shown, the tube becomes less and less stable and has a large apparent increase in transconductance. When the grid resistance has been increased too far the tube has only two stable points of operation. One of these is at a plate current of approximately 2.2 ma, corresponding

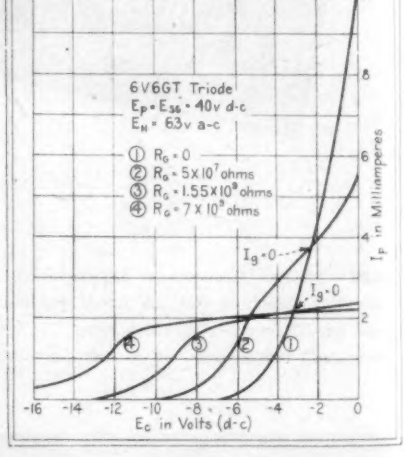

Fig. 5—E_G-I_P curves of a triode-connected 6V6GT with several values of grid-circuit resistance

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Simpson Shock Test — Instrument is mounted in sliding carriage, and dropped against bottom plate. Vertical scale permits shock of impact to be computed in multiples of g, the acceleration of gravity.

WHILE electrical instruments are delicate by their very nature, the conditions under which they must serve are seldom ideal—these days especially. Before entrusting them with vital responsibilities, it frequently becomes necessary to learn just how much abuse they can withstand.

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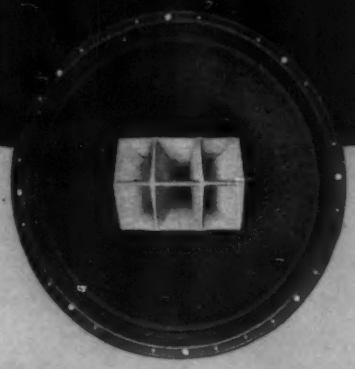

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to the point $I_o = 0$, and the other is zero plate current.

In order to have stable operation, it is necessary to use a grid circuit resistance sufficiently small that the IR drop across the grid resistance is small compared to the available grid swing. As an example, if the 6J5 of Fig. 2 were to be used it would not be advisable to attempt to use a grid circuit resistance greater than 25 megohms. With this grid resistor, the loss of bias due to grid current is a maximum of 0.1 volt. In many cases, this loss can not be tolerated and even less grid resistance can be used.

Comparison

Figure 6 is probably the most significant set of curves presented. This shows the magnitude of variations in grid current that may be expected from tube to tube. Tube No. 1 is the best of a group of 12

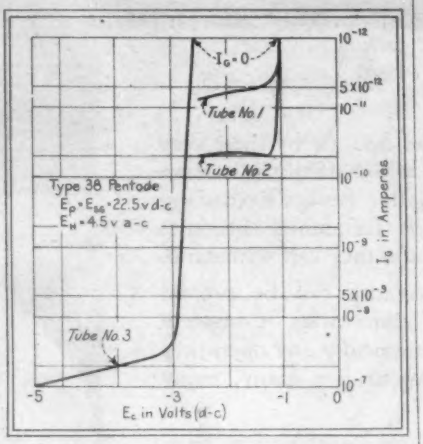
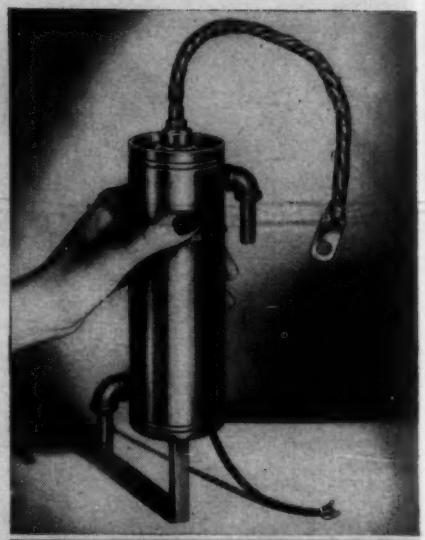


Fig. 6—Curves of grid current obtained from three tubes of the same type

type 38 tubes purchased about three years ago. Tube No. 2 is an average tube and tube No. 3 is a very poor tube which was purchased recently. This is not meant to infer that tubes of recent manufacture are poorer with respect to grid current than older tubes since only two recent tubes were available for test. It is quite obvious from this data that the type 38, on the average, shows superior grid-current characteristics.

Two tubes, whose grid current approximated that of tube No. 1, were used in a balanced bridge circuit for measuring small light intensities falling on a pair of type-929 phototubes. The amplifier was stable, and reliable data was ob-



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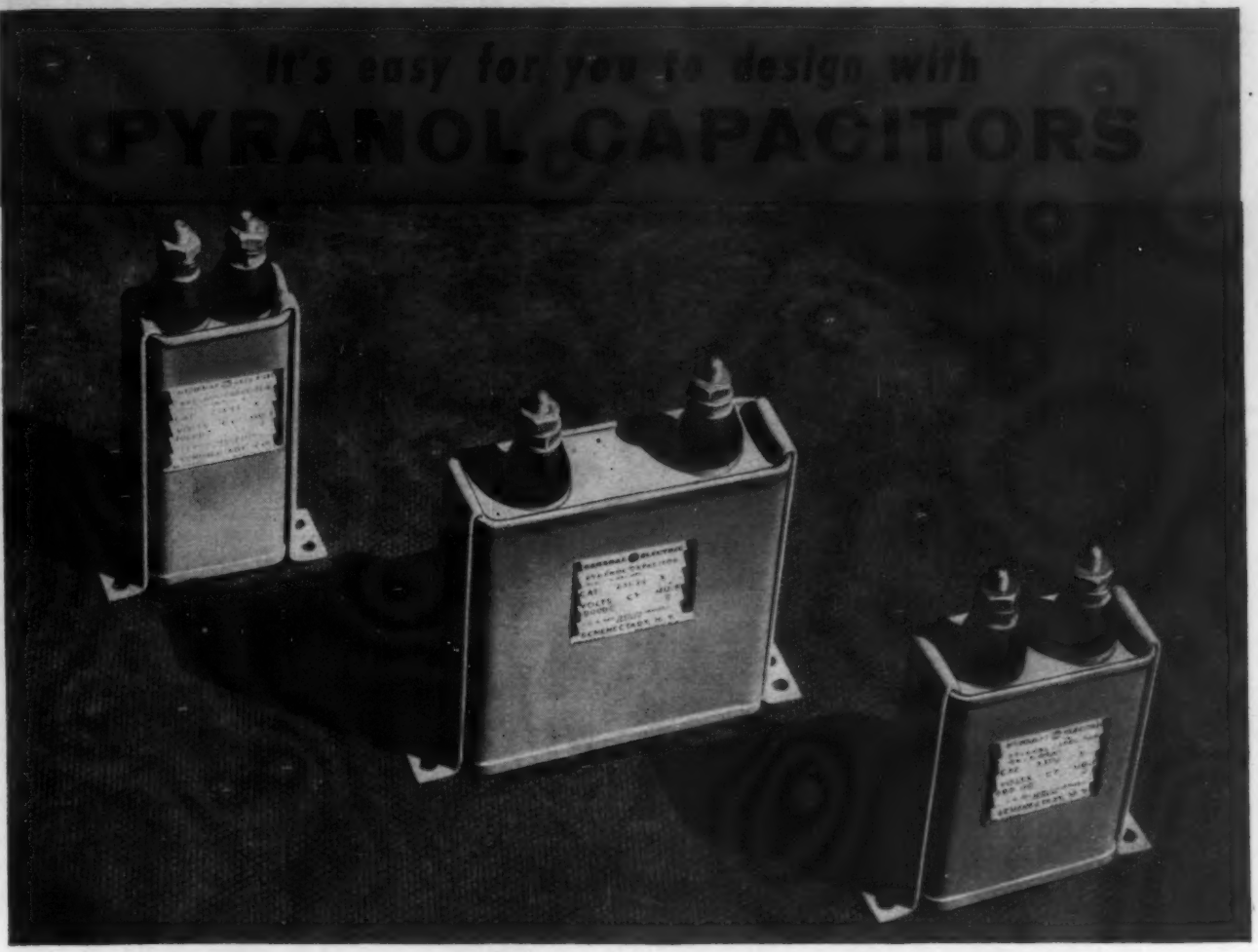

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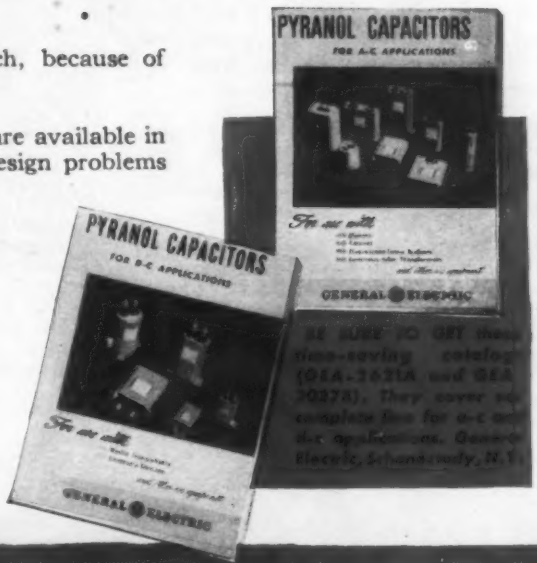

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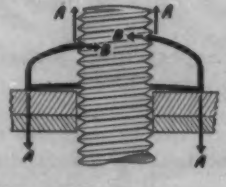


When the Palnut is tightened, its arched, slotted, spring steel jaws grip the bolt like a chuck (B-B), while spring tension is exerted upward on the bolt thread and downward on the part (A-A), securely locking both.

Self-Locking PALNUTS

tained at light levels which gave a photo current of approximately 10^{-11} amperes. A grid circuit resistance of 5×10^{9} ohms was used.

It may be concluded from this data that grid circuit resistance up to a possible maximum of 5×10^{7} ohms can be used with a number of the common receiving type vacuum tubes. If it is necessary to go higher than this, it will be necessary to pick the tubes to be used by actual measurement of grid current and to operate the tubes at a plate voltage not exceeding about 40 volts and a heater or filament voltage 20 percent below normal.

• • •

Electronarcosis Therapy

THE USE OF AN ELECTRIC current for inducing convulsions was reported by Cerletti and Bini in 1938, and since then this method has gradually replaced both insulin and convulsant drug therapy.

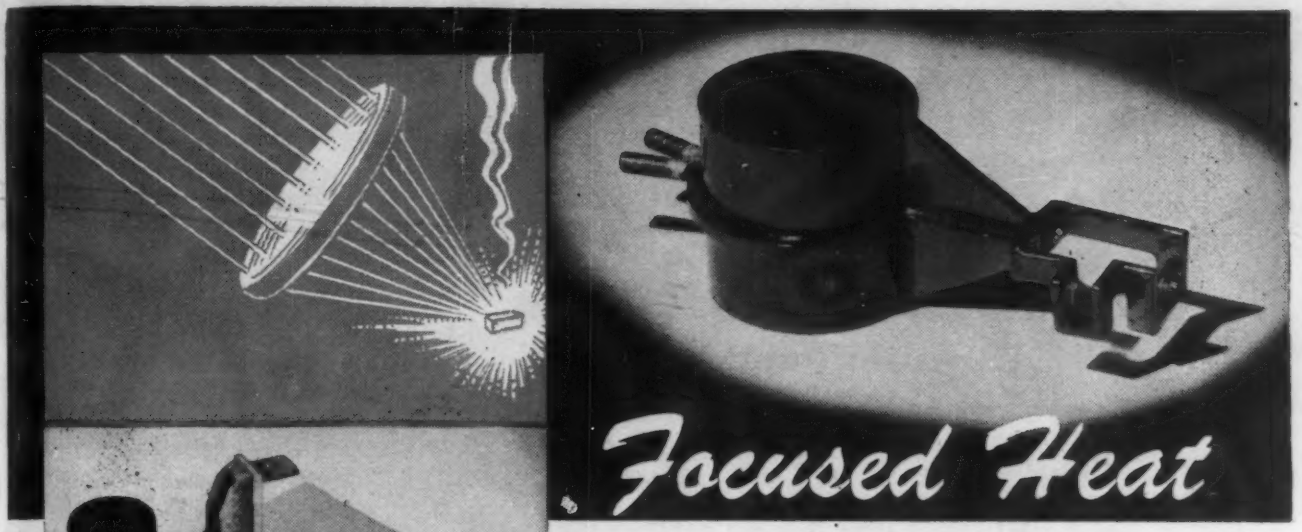
Insulin has been used in the treatment of insanity for several years. A coma is produced by the injection of sufficient insulin to reduce the blood sugar to a point where the patient is unconscious. This condition is maintained for some time and is often accompanied by convulsions.

It was noted by many psychiatrists that these convulsions seemed to produce an especially marked improvement in the patient's mental condition, so various more directly convulsant drugs were used. About the same effect was produced with a considerably simpler technique.

In the electroshock treatment, an electric current is passed through the brain by the application of conducting electrodes to the intact scalp on the sides of the head. From 70 to 150 volts at a frequency of 60 cycles is usually applied for a period of 0.1 to 0.5 seconds. (An electronic timer for this purpose is described by Paul Traugott in the November, 1943 issue of ELECTRONICS and its circuit is shown in the illustration.)

Brain Current

The total current flow between the electrodes is ordinarily between 300 and 1000 ma. A very small percentage of this current actually passes through the brain, most of it



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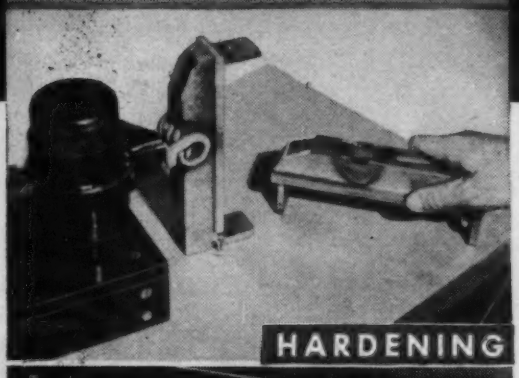

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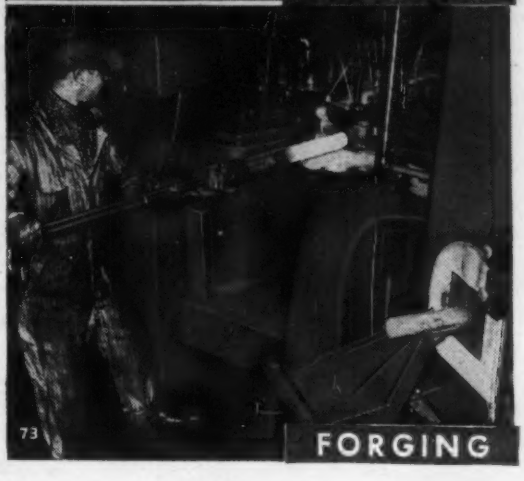

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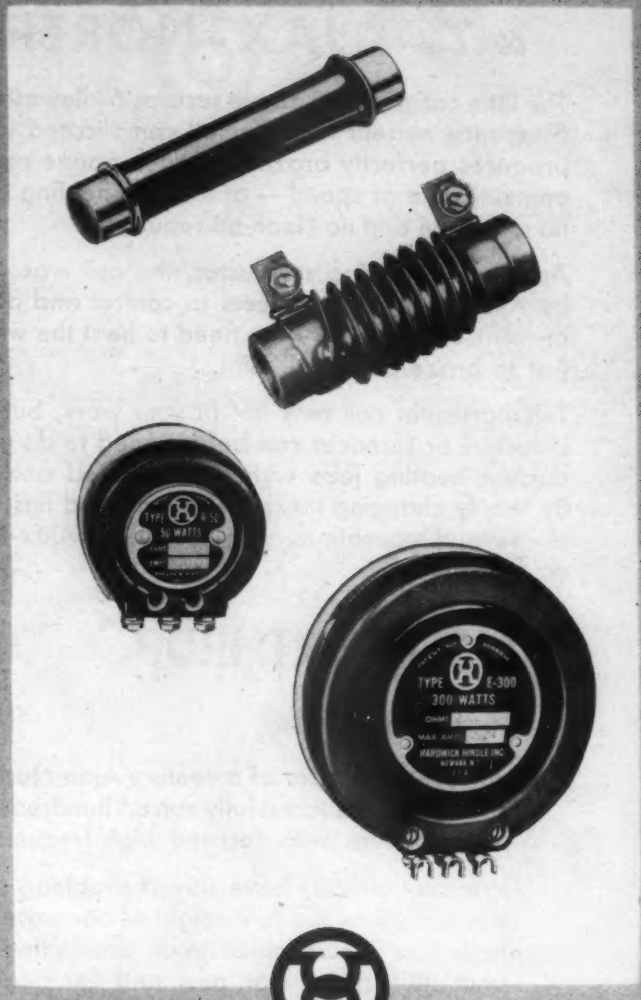

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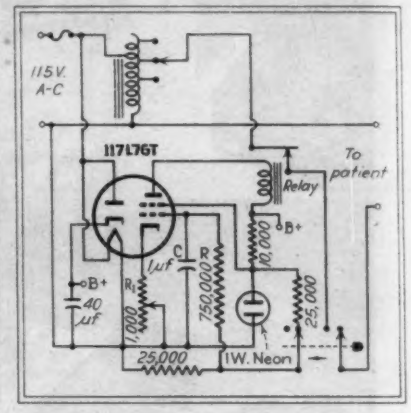
flowing through the scalp. When the current is applied, the patient goes into a convulsion closely resembling an epileptic seizure, which ceases in a few seconds. He usually becomes conscious in 9 or 10 minutes, but remains somewhat confused for about a half hour. Excellent results have been reported with this method in some types of insanity especially manic depressive psychosis and schizophrenia.

An interesting variation of the above method is electronarcosis, described by Drs. Frostig, van Harreveld, Reznick, Tyler, and Wiersma in the *Archives of Neurology and Psychiatry*, 51: 232–242, 1944. In 1902, Leduc produced electronar-



Circuit of electronic timer for control of therapeutic electric shocks. The neon bulb is used as a voltage stabilizer in the screen-grid circuit

cosis in dogs by passing a unidirectional pulse current from the head to the sacrum, and later tried it on himself, with the assistance of Malherbe and Rouxeau. After the application of the electrodes, the current was slowly increased. At a low level there was considerable discomfort at the site of the electrodes, which ceased on further increase of the current. He soon lost his ability to speak, and at a slightly higher level was unable to move. He heard what was said to him, but understanding was dreamlike and painful stimuli felt dull and far away.

About 1910, electronarcosis was used as a method of anesthesia in a few clinical surgical operations with some success. The present study was apparently not made with electrical anesthesia especially in view, but to elucidate further the physiology involved. The first experiments were performed on dogs.

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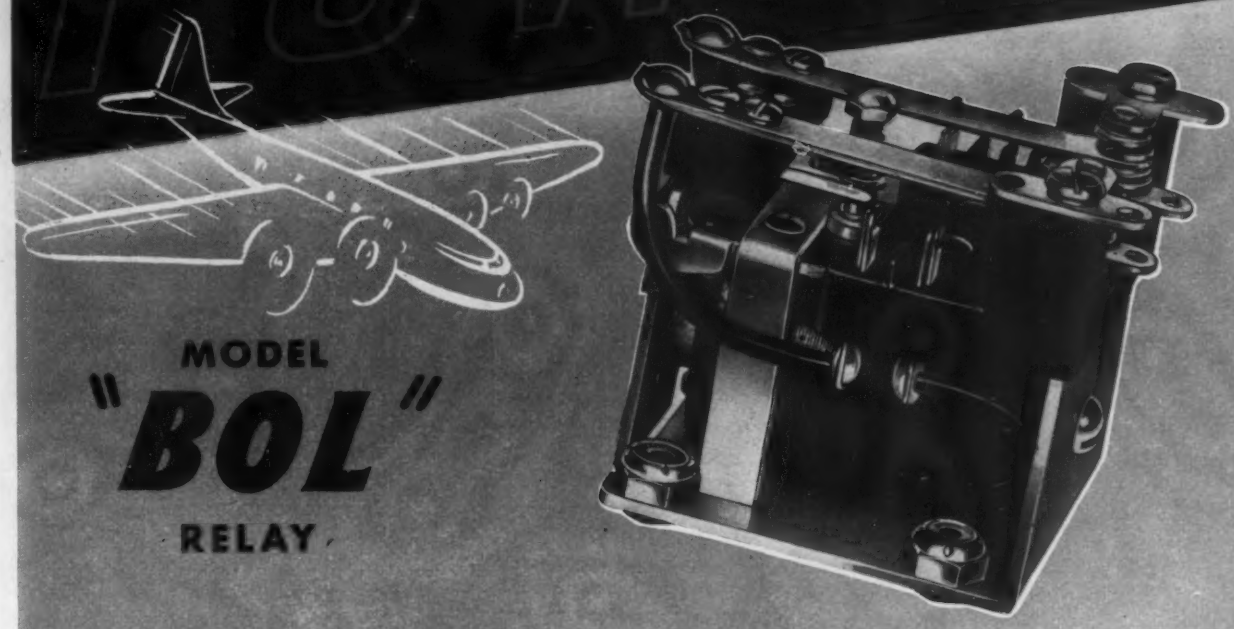

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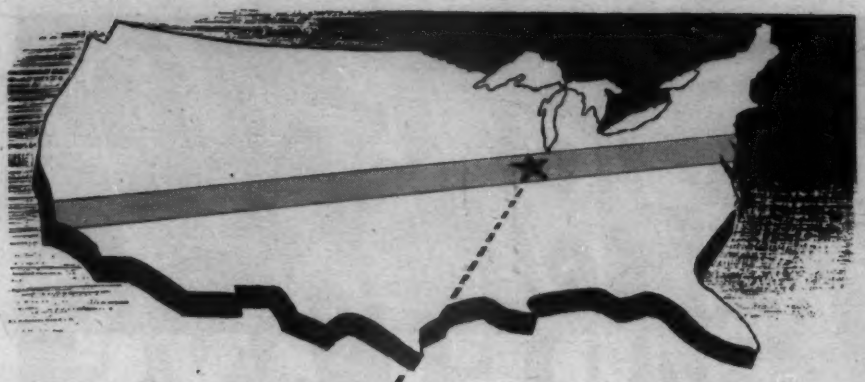

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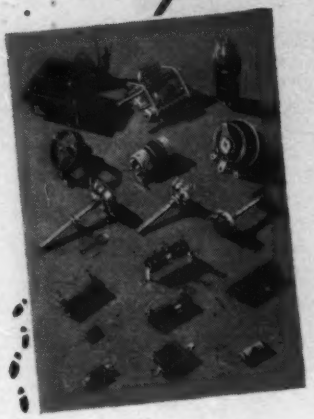

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the later experiments on schizophrenic patients as a variant of the standard electroshock therapy.

Apparently any current capable of stimulating the central nervous system can be used to produce electronarcosis. This requires a moderately rapid variation of current in duration and slope, repeated at a suitable frequency. Sixty or fifty-cycle alternating current is most generally available, so all of the experiments were done with this power source.

Effect on Humans

In the dog, it was found that the symptoms shown on application of the current were quite variable, ranging from a quiet narcosis to violent convulsions. In man, there are always some convulsive symptoms present but they never reach the intensity shown in the dog. The initial current used was 150 to 250 ma for thirty seconds, after which it was decreased to a point where respiration returned, between 45 and 90 ma. Nine schizophrenic patients were used as the subjects in the human experiments and a total of over 100 electronarcoses were induced. All had shown signs of dementia praecox for over four years, and were physically healthy.

Application of the current was immediately followed by a lightning-like movement of the arms and legs, followed by a phase of rigidity. The chest was fixed in a position of maximal inspiration and there was complete arrest of respiration during the high initial current flow. It usually resumed after reduction of the current to the lower prolonged level, but was sometimes delayed for a total of 50 to 70 seconds. The heart stopped beating for a few seconds after current flow started and then started again at a low rate, about 20 per minute. The eyes were closed and the pupils were constricted and did not react to light. In women, an erection of the nipple occurred.

When the current was decreased, the rigidity ceased and there were usually a few seconds of coarse shaking and clonic twitches. The patient was then in a relaxed stage for three to five minutes. Spontaneous movements, primitive in character, appeared thereafter. The supine patient tried to roll over or sit up. Reflexes, which had been ab-

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sent during the earlier period, began to reappear. The pupils began to react to light. After the initial symptoms had passed, the respiratory and heart rates were considerably higher than normal.

Subject's Sensations

The patients were unconscious during the entire applications of the current, but some patients stated that they remembered a flash of light at the beginning of the treatment, which may have been due to the stimulation of the optic system by the high initial current. It is interesting to note that according to the results obtained in electroshock therapy and electronarcosis, electrocution is apparently completely painless. No patient reported any unpleasant sensations during electronarcosis. A few minutes after termination of the treatment the patient usually reacted to his name and a few minutes later tried to answer questions.

In the dog, the placement of the electrodes had little effect on the results, which would be expected because the brain of the dog is quite small in comparison to the muscular and bony covering. These factors tend to equalize the current flow in various parts of the brain.

In man, the main symptoms of electronarcosis were unchanged by the placement of the electrodes, but there were minor differences. Low placement of the electrodes caused a profuse secretion of saliva and tears, which was not present with the electrodes higher on the head. With the electrodes over the front part of the skull, the pupils were constricted and did not react to light in the first period of the electronarcosis. With the electrodes farther to the back, the pupils were less constricted and reacted to light earlier. With the occipital location, there was greater respiratory depression than with the frontal location.—W.E.G.

WHEN GENERAL INGLES was in the South Pacific, he visited one headquarters in New Guinea which consisted of a one-story shack made of salvaged lumber and grass. He said he began to feel at home when he saw a sign as tall as the shack, on which was painted "The Pentagon."

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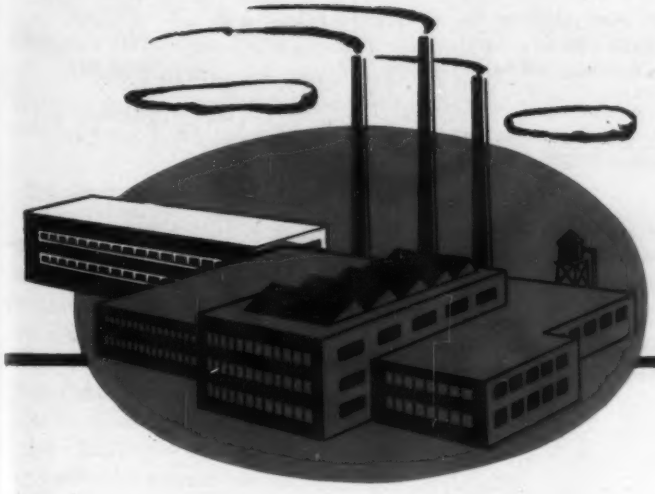

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Pan-El QUANTITY PRODUCERS OF STANDARD AND SPECIAL Control Crystals

Capacitor Plates

(*Continued from page* 136)

one that makes E a minimum.

Adding T to both sides of Eq. (17) gives

$$S + T = \frac{v}{E} + \frac{v^2}{\pi E^2 T} + T \qquad (18)$$

Differentiating Eq. (18) with respect to T, remembering that $(S + T)$ is constant, and then equating dE/dT to zero results in the condition

$$\frac{v}{E\,T} = \sqrt{\pi} \qquad (19)$$

Substituting Eq. (19) in (17) results in

$$S/T = 1 + \sqrt{\pi} = 2.77 \qquad (20)$$

as the best ratio of plate spacing to plate thickness. Note that the best value of S/T as found above falls within the limits suggested by Ekstrand.

Alternate Forms

Equation (17) may be made more symmetrical by dividing through by T.

$$\frac{S}{T} = \frac{v}{E\,T}\left(\frac{v}{\pi E T} + 1\right) \qquad (21)$$

Another useful form is

$$\frac{E}{E_{av.}} = \frac{1}{2}\left(1 + \sqrt{1 + \frac{4S}{\pi T}}\right) \qquad (22)$$

where $E_{av} = v/S$.

The form of Eq. (21) suggests that it may be generalized into

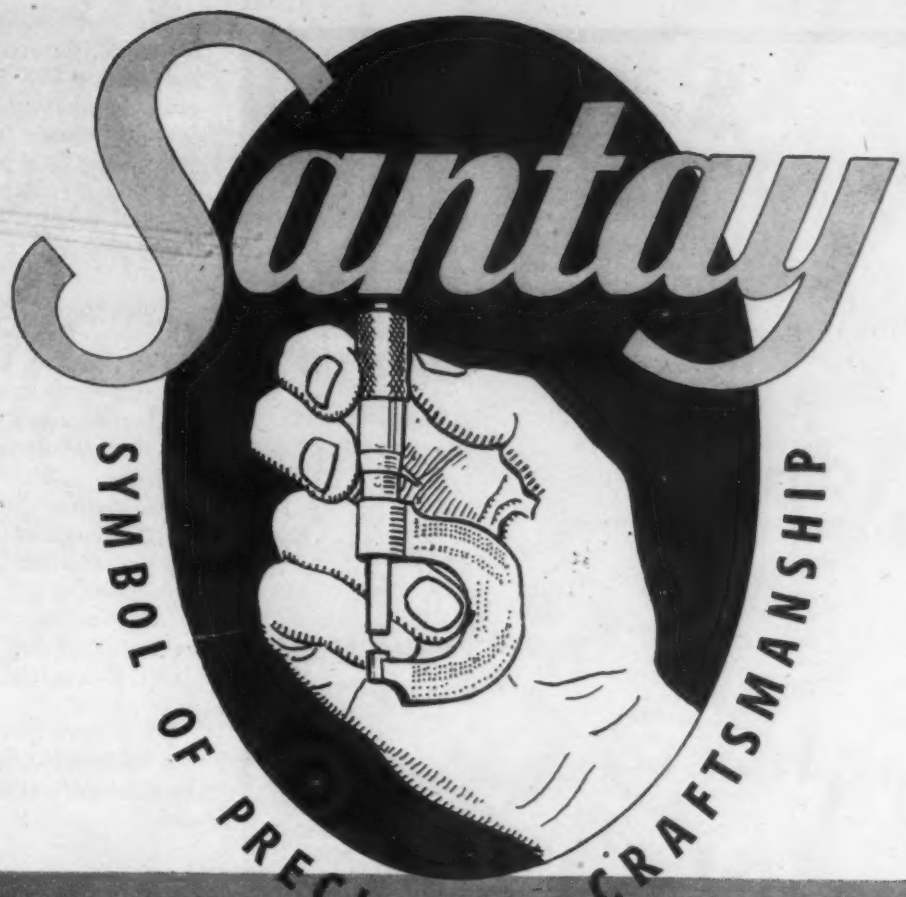
$$\frac{S}{T} = \frac{v}{ET} + \sum_{n=0}^{n=\infty} K_n \left(\frac{v}{ET}\right)^n \qquad (23)$$

where K_n is to be determined by experiment.

Ekstrand[2] published some measurements on the sparkover voltages of three capacitors with rounded edges at frequencies of 60 cycles, 700 kc and 1500 kc. Table (1) lists calculated values of maximum gradients on these capacitors as determined by means of Eq. (22). Any modification by corona of effective plate thickness has been neglected.

Frequency-Independent Sparkover

At 60 cycles, the calculated maximum gradients at sparkover do not vary more than about ten percent, with a mean value of 83.8 kv per inch. This value for the sparkover gradient is of the expected order for low frequencies. Only one ca-



SANTAY CORPORATION

FORMERLY SINKO TOOL & MANUFACTURING CO.

351-359 NORTH CRAWFORD AVENUE • CHICAGO 24, ILLINOIS

REPRESENTATIVES: POTTER & DUGAN, INC., 29 WILKESON STREET, BUFFALO 2 • PAUL SEILER, 7779 CORTLAND AVENUE, DETROIT 4 • QUEISSER BROS., 108 E. NINTH STREET, INDIANAPOLIS 2

Santay Corporation introduces its new trademark –

"Symbol of Precision Craftsmanship!"

Whenever you see it associated with a thermoplastic product, metal stamping or electro-mechanical assembly, you'll know that Santay's specialized precision craftsmanship has been and always will be employed to give you the greatest possible satisfaction.

1. **DOUBLE Protection Against Loose Anodes**
2. **LARGER, Heavy-duty Carbon Anode**
3. **Withstands High - peak Inverse Voltages with No Arc Back**
4. **Designed for ROUGHER Use — Withstands Vibration**

IDEAL for INDUCTION HEATING

MAXIMUM PEAK INVERSE ANODE VOLTAGE (25-150 cycles) = 20,000 volts.

Maximum Peak Anode Current (25-150 cycles) = 10 amperes
Average Anode Current 2.5 amperes (In-phase filament excitation)

Typical Conditions in A Single Phase, Full-Wave Circuit (2 tubes)

A.C. Input voltage, 7070 (RMS per tube)—D.C. Output voltage, 6360
Maximum D.C. Load current—5 amperes

ARPIN 575-A MERCURY VAPOR RECTIFIER

Two tubes for full-wave rectification in single phase circuits deliver 5000 volts D.C. at 3 amps. with good regulation. Filament 5 volts, 10 amps. Peak plate current 6 amps. Peak inverse voltage 15,000 volts. Fully guaranteed.

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ARPIN MANUFACTURING CO. 422 Alden Street Orange, New Jersey

pacitor, with a ratio of S/T equal to 1.705, approximates this value for 700 and 1500 kc. The other two give breakdown gradients progressively lower for increasing frequencies. These facts seem to indicate that a critical value may exist for S/T, below which sparkover becomes relatively independent of frequency.

Note that the sparkover performance of these three capacitors at 60 cycles can be predicted from Eq. (22), at least to common engineering accuracy. For use in testing this relationship further, Eq. (21) and (22) are plotted in Fig. 2.

Implications of the foregoing analysis suggest several leads for experimental verification or qualification, as follows:

(a) Verification of the best value for S/T.

(b) Evaluation of K_n in Eq. (23).

(c) Determination of the relation between corona onset and the radius of curvature of the plate edge.

(d) Effect of increasing frequency.

References

(1) Peek, F. W., "Dielectric Phenomena in High Voltage Engineering," third edition, McGraw-Hill Book Co., 1929, p. 30-31.
(2) Ekstrand, P. A., Radio-Frequency Spark-Over in Air, *Proc. I. R. E.*, 28, No. 6, June, 1940, p. 262-266.
(3) Same as (1), chapters 4 and 5.
(4) Darrow, K. K., "Electrical Phenomena in Gases," Williams and Wilkins Co., 1932, chapter 9.
(5) Ollendorf, R. R., and Pohlhausen, K., "Theory of Functions," Technology Press, 1942, p. 138-140.

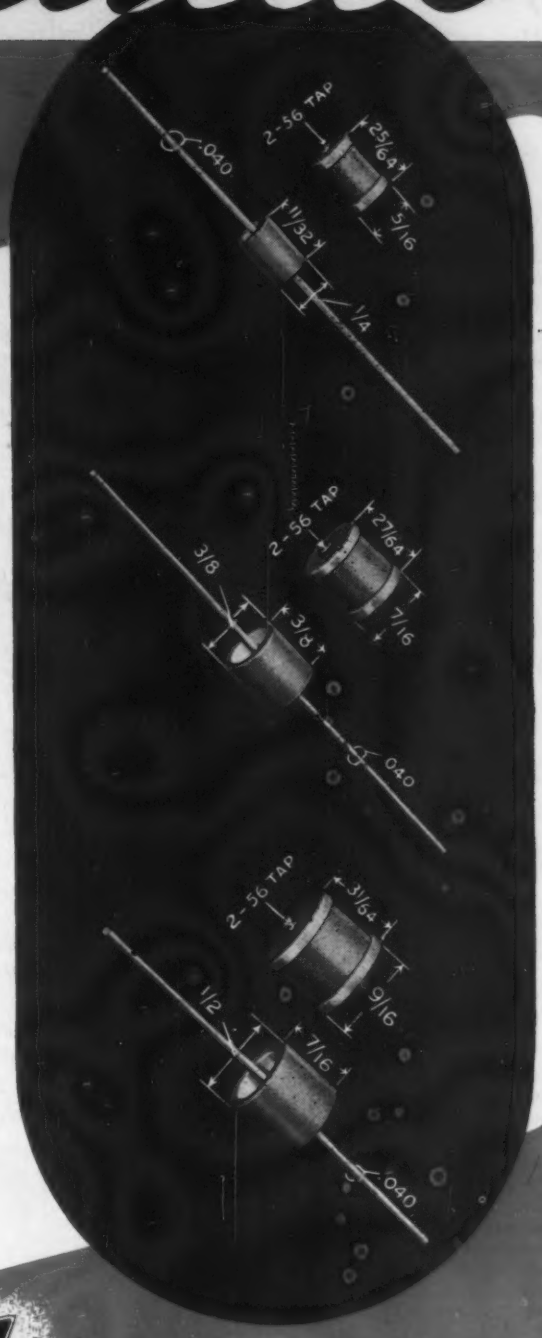
• • •

X-RAY CLIPPER SPARS

To insure safety in flight, duralumin spars of the extensive wing section of a Clipper are x-rayed for possible hidden flaws that escape visual inspection

Centralab

CERAMIC CAPACITORS *for* HIGH VOLTAGE



These capacitors are engineered by Centralab for special applications . . . accumulative capacities ranging from 2MMF to 20MMF in zero temperature coefficient . . . to 4MMF to40MMF in maximum negative (N750 PPM) temperature coefficient.

Individually the capacity ranges are as follows:

855	2MMF to 5MMF in zero T. C. 4MMF to 10MMF in N750
854	5MMF to 10MMF in zero T. C. 10MMF to 20MMF in N750
853	10MMF to 20MMF in zero T. C. 20MMF to 40MMF in N750

Working voltages from 8,000 to 10,000 D.C. Energy dissipation up to 2 KVA with 15°C rise.

End lead or axial screw terminals available.

Send for Bulletin No. 814.

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Producers of Variable Resistors • Selector Switches • Ceramic Capacitors, Fixed and Variable • Steatite Insulators.

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CRL

Division of GLOBE-UNION INC., Milwaukee

NEWS OF THE INDUSTRY

Television possibilities; postwar technical education; Coast-Guard radio; plant broadcasting; relay experiments; conventions; notes from Washington on production, station sales, and communications fellowships

Toward a Standard Television Picture Tube

ONE STANDARD flat-faced 10-in television picture tube may result from activities of Corning Glass Co., makers of the envelopes for practically all cathode-ray tubes. Heretofore it has been impossible to use automatic equipment on production of envelopes because of the wide range of sizes, shapes, and compositions. Hand-made techniques have been responsible for high prices.

A special new department at Corning will combine the development of envelopes with development of machinery for large-quantity production. Having surveyed the field, the company feels that standardization is quite feasible, with particular interest having been shown in the 10-in. size. Resulting picture will be six by eight, a new size for American receivers, though used in British sets. Demand is estimated at one million tubes a year.

Costs for Television Broadcasting Equipment

CONSIDERING THAT 480 of the 917 broadcasting stations in the U. S. have invested less than $30,000 in equipment, Leonard F. Cramer, executive vice president of Allen B. DuMont Laboratories believes the average prospective television broadcaster of the future will be thinking in terms of station costs near $250,000. Speaking recently to the television seminar of the Radio Executives Club of New York he presented the following figures based on pre-war costs:

Studio Equipment and Transmitter	
2 Iconoscope cameras mounted on push dollies; Studio Control Desk	$23,000
Electrically controlled camera dolly	2,500
2 Special film projectors	12,000
2 Iconoscope film pickup cameras	6,000
Master control board	35,000
Transmitter, 25 kw video—12.5 kw audio, with control console	65,000
Antenna	10,000
	$153,500
Field Pickup Equipment	
2 Field pickup cameras with controls	$24,000
Relay transmitter	8,000
Relay receiver	2,000
Field audio equipment	1,500
Truck with generator and antenna	5,000
	$40,500
Installation, Sound, Lighting	
Studio installation	$15,000
Soundproofing, elec. wiring, etc.	25,000
Studio lighting, sound equipment, etc.	10,000
Fireproofing film studio	1,500
Equipment spares and test instruments	13,000
	$64,500
TOTAL	$258,500

Middle East

MARVIN CAMRAS, right, inventor of the magnetic wire recorder developed at Armour Research Foundation, demonstrates its features for Louis P. Birk, director of public information for the United Nations

Relief and Rehabilitation Administration. The unit is to be taken to the Middle East for use in refugee camps. Health and hygiene, friendly relations, and public information and instruction will be featured.

Rochester Meeting Program

TECHNICAL PAPERS scheduled to be presented at the Rochester Fall War Conference on Nov. 13 and 14 include the following subjects:

The Reactance Theorem for a Resonator, by W. R. MacLean, Polytechnic Inst. of Brooklyn.

A Resonant Cavity Method for Measuring Dielectric Properties at U-H-F, by C. N. Works, T. W. Dakin, F. G. Boggs, Westinghouse Elec. & Mfg. Co.

The RCA Laboratories at Princeton, by E. W. Engstrom, Radio Corp. of America.

Low Frequency Compensation of Multistage Video Amplifiers, by M. J. Larson and A. E. Newlon, Stromberg-Carlson Co.

Trends in Receiving Tube Design and Application, by L. R. Martin, Radio Corp. of America.

Standardization of Capacitors for Civilian Equipment, by J. I. Cornell, Solar Mfg. Corp.

Report of RMA Director of Engineering, W. R. G. Baker.

The Organization of Research in the Radio Industry after the War, by Rupert Maclaurin, Massachusetts Inst. of Technology.

Electronic Tube Trends, by R. M. Wise, Sylvania Electric Products Inc.

Silicone Products of Interest to the Radio Industry, by Shailer L. Bass and T. A. Kauppi, Dow Corning Corp.

Designing Thoriated Tungsten Cathodes, by H. J. Dailey, Westinghouse Elec. & Mfg. Co.

Salvage of Electronic Products

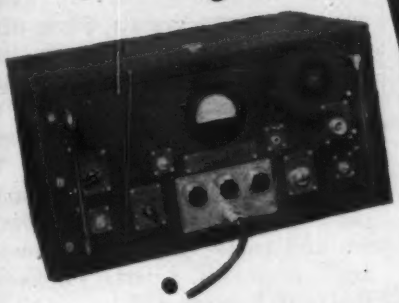
TO SALVAGE AND RECLAIM every type of electronic product used by the Navy, six material and redistribution centers are being established on the Pacific Coast. Obsolete, battle-worn, and surplus equipment is to be reclaimed, and redistributed as replacements, spare parts or scrap. Centers will be at Irvington, Stockton, Torrance, and San Francisco, Calif., and Salem, Ore.

Walkie-talkies are the particular consideration of recent instructions sent by the Signal Corps of the Army to signal depots in the U. S. and abroad. Older reradiating models are dismantled and stripped of 85 parts, 27 of which can be reused in or with other Signal Corps equipment. Even the quartz crystals are turned over to a field regrinding unit for further use. Resistors and capacitors with pigtails less than an inch are reluctantly scrapped.

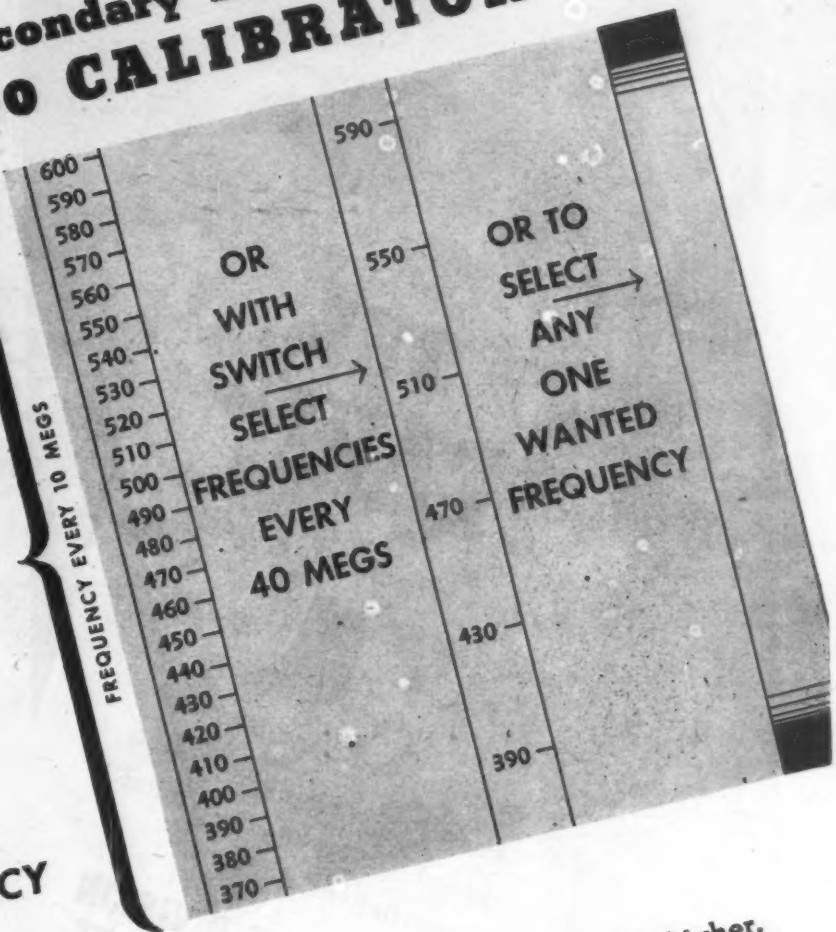
Elections in RMA

RECENTLY ANNOUNCED department directors of RMA include: by-laws and organization, Leslie F. Muter; engineering, W. R. G. Baker; industry reconversion, A. W. Wells; NEMA tube classification, W. R. G. Baker; RTPB television reporting,

the NEW, Secondary Standard
LAVOIE C-200 CALIBRATOR



WILL PRODUCE HARMONICS FROM 10 TO 2000 MEGACYCLES AND HIGHER WITH QUARTZ-CRYSTAL ACCURACY



The LAVOIE C-200 CALIBRATOR...

1. Produces only harmonic frequencies of 10 megs up to 2000 megs or higher.
2. By means of a switch cuts out 10's and produces only 30's on the megacycle frequency range.
3. By means of the Identifier, selects any one frequency for purposes of identification.
4. Is equipped with a detector and amplifier on the panel for use with calibrating signal generators, etc., etc.

Write for detailed information.

U H F

Lavoie Laboratories

RADIO ENGINEERS AND MANUFACTURERS

MORGANVILLE, N. J.

Specialists in the Development of UHF Equipment

AT THE PEAK!
Helping to maintain a great public service at the peak of its efficiency, BLAW-KNOX towers are serving America's war-time radio industry from coast to coast . . . delivering broad coverage with maximum dependability.
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FM & TELEVISION TOWERS

Ray H. Manson. In the transmitter division, the following section chairmen have been listed: radio transmitter tubes, H. C. Vance; broadcast transmitters, C. W. Miller; emergency service communication, F. A. Gunther; aviation equipment, J. W. Hammond; marine equipment, F. R. McMullen; and piezoelectric quartz crystals, G. E. Wright.

Other section chairmen are: school sound systems, amplifier and sound equipment division, Laurence A. King; crystals, parts division, F. D. Bliley; insulations (tubing, tape, sleeving, varnishes, and sealings), parts division, John W. Apgar; metal stampings and metal specialties, parts division, W. W. Barry; plastics and molded parts, parts division, R. R. Titus; speakers and parts (including headsets and magnets), parts division, Henry C. Forster.

Police Lineup by Television

A NEW WEAPON for the apprehension of criminals after the war may well be the telecast police lineup by which a central station might familiarize police over a large area with the lawbreakers under current custody. Speaking before a meeting of the New York State Association of Chiefs of Police, Commissioner Edward J. Hickey of the Connecticut State Police hoped such facilities might be available to combat a possible post-war crime wave.

In another talk at the same conference, Frank J. Wilson, chief of the U. S. Secret Service suggested that similar facilities could be used to make the public familiar with the particular tricks of confidence men thought to be operating in a certain area, to dramatize the conditions leading to juvenile delinquency, and to generally aid in law enforcement.

Large-Screen Television Prospects

BASED ON USE of the Skiatron and supersonic light relays which make it possible to project a great number of picture elements simultaneously, Scophony Corp. of America expects to merchandise a postwar home television receiver with a flat, projected picture 18 x 14½ in. for a price somewhere in the vicinity of $200.

A similar model was introduced

HIPERSIL* CORES

HIPERSIL* CORES

Reduce weight 40%

This aircraft transformer is tangible proof of the weight and space savings made by Hipersil Cores.

With them, engineers cut the weight of the transformer to 8 ounces, approximately 40% less than the nearest competitive item of the same output. The unit has a low temperature rise of 30° which permits operation over all ambients from minus 65° to plus 70° C at all altitudes up to 50,000 feet.

Hipersil Cores release engineers from the limitations of ordinary silicon steel. Hipersil affords a wider range of linear response... approximately ⅓ greater straight-line response for winding and core section. Construction is simplified because there are no "tissue-thin" laminations to stack . . . only 2 or 4 pieces to handle. Learn the facts about Hipersil. Write for Booklet B-3223. Address: Westinghouse Electric & Manufacturing Co., P. O. Box 868, Pittsburgh 30, Pa. J-70433

HIPERSIL CORES COMBINE THESE ADVANTAGES:

- 30% to 50% lighter weight
- 33⅓% more flux-carrying capacity
- Very high, high-density permeability
- High, low-density permeability
- High incremental permeability
- Very low losses in direction of rolling
- Space factor as high as 95% . . . thin glass films insulate adjacent laminations.

*Registered Trade-Mark Westinghouse Electric & Mfg. Co., for High PERmeability SILicon steel.

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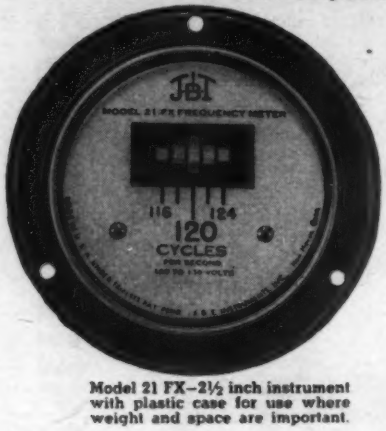
PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

Jungle-Proof FREQUENCY METERS

Jungle Conditions—One of the laboratory tests simulating field use is a minimum run of 120 hours at 120° F, 95 RH. Component parts have previously been tested at 180° F.



Model 21 FX—2½ inch instrument with plastic case for use where weight and space are important.

IF you had to work in a jungle, the stifling heat and humidity approaching the saturation point might get *You*... but *not* J-B-T Frequency Meters. These meters can take it... and do... heat and moisture notwithstanding.

Suspended in open bottom bell jars over steaming water, J-B-T Frequency Meters consistently indicate correct frequency or speed although dripping wet. This is so because in J-B-T simplified construction, the only moving part is the reed, which *throws off* moisture as it operates, and because all component parts are protected by the most advanced moisture-resistant finishes.

Jungle-proofing is not the only assurance of reliability. J-B-T Vibrating Reed Frequency Meters are also unaffected by mechanical shocks, voltage drop, change in wave form or external magnetic fields.

Send for illustrated bulletin VF-43 including VF 43-1A on 400 cycle meters and VF 43-1B on the new compact 2½ inch meters.

J-B-T

(Manufactured under Triplett Patents and/or Patents Pending)

J-B-T INSTRUMENTS, INC.

431 CHAPEL STREET • NEW HAVEN 8, CONNECTICUT

19-JBT-2

in England just before the war, priced at £70 or approximately $350 at prewar sterling rates. The lower price will depend upon large-scale production, according to Arthur Levey, president of the company, who addressed a recent session of the television seminar of Radio Executives Club in New York recently. A larger model which included the same electronic gear, but a modification of the optical system, produced a picture 24 x 20 in.

Among company developments, some of which are currently connected with secret projects, is a scrambling device which makes it possible for television programs to be directed to special, authorized subscribers, while television projection for theaters is anticipated through the company's connection with Paramount Pictures. Projected pictures 18 ft wide were used successfully in two London theaters before the war.

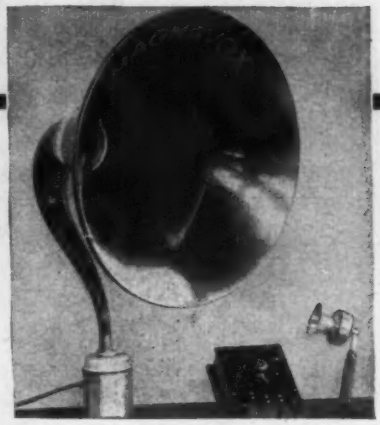
Postwar Educational Trend

ACCORDING to the G.I. Bill of Rights, every eligible veteran will have about $1,000, exclusive of his bonus, to spend studying for a better peacetime job. In 1939 there were 125 students in technical and trade schools to each 100 in regular college. Feeling that many of the veterans will prefer trade school preparation to courses in history, literature, or foreign languages, a group of technical schools is forming a trade association, headed by Dr. J. S. Noffsinger, Washington, D. C., to raise standards of ethics, improve courses, and bring technical schools in closer touch with industry. Individual schools will be inspected, revised, and placed on an approved list which will give their graduates greater prestige among employers.

Coast-Guard Radio

CELEBRATING ITS 154th anniversary, the U. S. Coast Guard points out that its history includes pioneer work on ship and aeronautical radio. The Revenue Cutter Service, as the Coast Guard was called then, first used wireless telegraphy in 1903 for ship-to-shore communication. Credit for establishment of the standard 500-kc distress fre-

THERE IS NO SUBSTITUTE FOR EXPERIENCE



In 1915 Magnavox engineers produced this "daddy" of all loud speakers—the horn-type electro-dynamic speaker. Today the electro-dynamic loud speaker is the "voice" of modern sound reproduction in radio, sound motion pictures and all other kindred fields.

In 1922 Magnavox engineers developed this historic instrument—the first amplified radio-phonograph. As the forerunner of all present day radio-phonograph combinations, it marked an important advance in the development of sound reproduction.

THESE EXAMPLES serve to remind us how closely the history of radio is interwoven with that of the Magnavox Company.

In 1911 the electro-dynamic reproducer, developed by this company's engineers, completely revolutionized the art of sound reproduction. The same principle is used in all radios today.

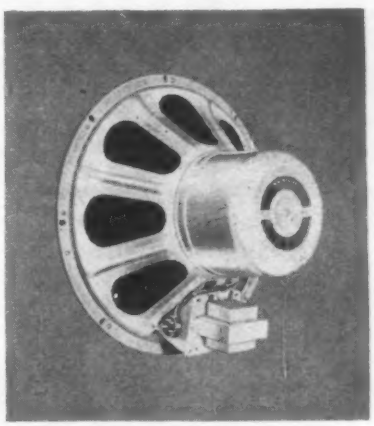
Magnavox for years has been not only the world's largest supplier of loud speakers, but also one of the largest producers of electrolytic condensers. This experience dates from the original "Mershon" to the current Magnavox type.

The experimental work that built the Magnavox reputation is constantly perpetuated—now intensified and broadened by highly diversified war work. Magnavox is your logical source for components and for cooperation in your future projects. The Magnavox Company, Fort Wayne 4, Indiana.

Magnavox

Loud Speakers • Capacitors • Solenoids
Communication and Electronic Equipment

Another important step forward was achieved with this first single-dial radio produced by Magnavox in 1923. Its importance at the time is appreciated when we remember that all previous radio sets required the use of three dials for tuning in a station.



The cone type of electro-dynamic speaker was introduced by Magnavox engineers in 1927. It was the prototype of all electro-dynamic speakers in use today, recognized throughout the world as the most efficient means for the electrical reproduction of sound.

500,000,000 to ONE

0.00002 TO 10,000 VOLTS

This enormous range of voltages—five hundred million to one—is accurately covered by our Model 300 Electronic Voltmeter and some of the accessories shown above. Frequency range 10 to 150,000 cycles. Accuracy 2% over most of the range. AC operation. Five decade ranges with logarithmic scale make readings especially easy. Uniform decibel scale also provided. May also be used as a highly stable amplifier, 70 DB gain, flat to 150,000 cycles.

BALLANTINE LABORATORIES, INC.

BOONTON, NEW JERSEY, U. S. A.

quency and for the use of the term "sparks" in connection with operators belongs to this service. Later, when the Revenue Cutter Service and the Life Saving Service had been merged to form the Coast Guard, radio was first used for aircraft communication and flight guidance. Detailed pioneering involved the rotatable electrostatically-shielded d-f antenna and cathode-ray direction indicating instruments.

Radio Relay Allocation

HITHERTO COMMERCIALLY unused frequencies have been allocated to American Tel. & Tel. Co. for experimentation on a radio relay system between New York and Boston. Facilities will be suitable for fm, facsimile, and television broadcast relay as well as telegraph and telephone communication.

Two Class 2, 10-watt stations are provided for in the present authorization, while seven fully automatic relay stations are planned for the intervening space. Cost is estimated at $1,000,000.

News by Plant Broadcast

MORE THAN 5,000,000 American workers have been kept up to date on recent military developments through sound systems installed in war plants from coast to coast. Stromberg-Carlson Company has conducted a survey among users of such apparatus.

Keeping the workers continually apprised as to the true situation has made it possible, at the same time, to utilize the driving power of the worker's reaction and to circumvent gossip.

Most of the plants reported casting their communication systems in this role had previously used them mainly for paging officials, broadcasting speeches, and in general utilizing the facilities in the manner of talking bulletin boards.

CONVENTIONS TO COME

Oct. 2–5. Forty-Ninth Annual meeting, Boston, Mass. INTERNATIONAL MUNICIPAL SIGNAL ASSOCIATION, Irwin Shulsinger, secretary, 8 East 41 St., New York, N. Y.

Oct. 5–7. NATIONAL ELECTRONICS CONFERENCE, Chicago, Ill., B. Dud-

That's a TRICK, Mr. Jones ...and we know it!

PLASTIC MATERIALS, you know, vary considerably. Not only in regard to physical properties *after* molding, but in regard to molding behavior as well. In other words, your plastic part has to be designed in full recognition of your material. That's why we say that the selection of material is another job for your custom molder!

But Kurz-Kasch does more than team up these two functions. In growing up with the plastics industry, we've found it wise to insist that experts on mold-making, molding and finishing add their opinions during the planning stage. This way, you can rest assured that your job will be estimated right—produced right—and delivered right on schedule.

This service is available from the moment you first wonder if plastics will fit into your program. In fact, that's the time to get the most out of it. We urge you to feel free to use it—now!

Why Kurz-Kasch for Plastics? Kurz-Kasch offers a 28-year-old reputation for thoroughly engineered, quality production. • One of the largest, best-equipped exclusive custom molding plants in the country—75,000 square feet of floor space with 125 compression and transfer presses of all sizes.

Complete mold-making and finishing facilities • Extensive production sequences of radio-frequency preheating equipment, with full experience in their use. Completely equipped shop for production of inserts • For satisfaction in plastics, key these facilities into your production line.

BUY BONDS! ALL YOU CAN — WHENEVER YOU CAN

KURZ-KASCH

For over 25 years Planners and Molders in Plastics

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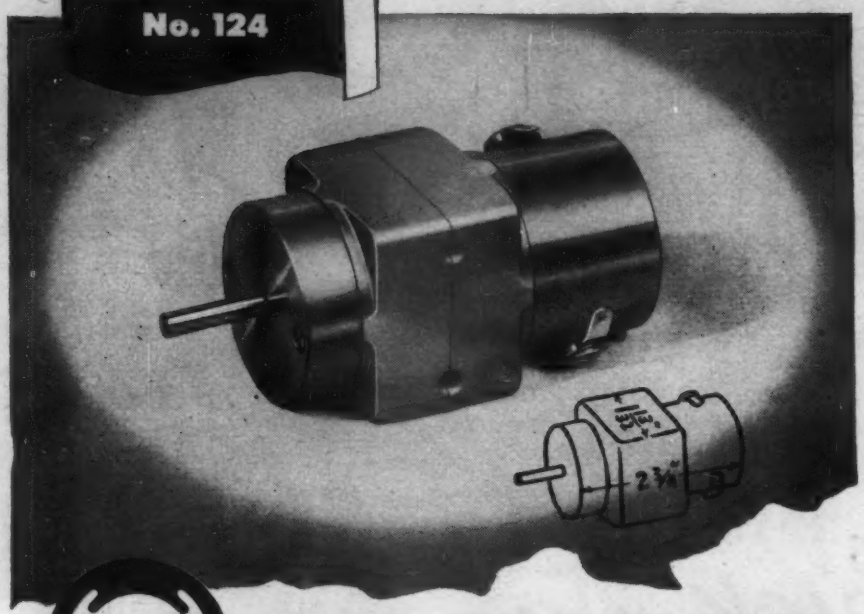
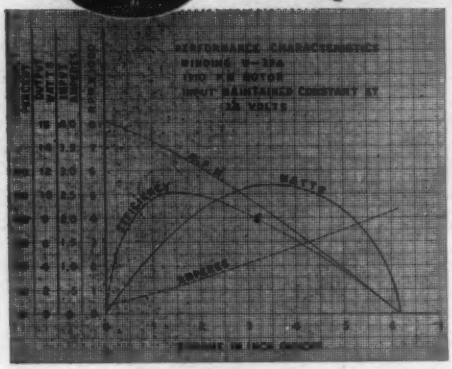
MOTOR DATA
No. 124



EICOR

PM MOTOR

Torque 3.5 in. oz. at 4500 RPM



PM MOTOR — 1310

Watts Output Int.	(max.)	11
Torque at 7000 RPM	(in.oz.)	1
Torque at 4500 RPM	(in.oz.)	3.5
Lock Torque	(in.oz.)	6
Volts Input	(min.)	5
Volts Input	(max.)	32
Temperature Rise Int.		50°C
Weight		11 oz.
Shaft Diameter	(max.)	.250"
Length less Shaft		2¾"
Overall Diameter		1 13/32"

Unique in design and construction, this permanent magnet field motor has been selected for many applications having critical space and weight factors. Wound as a shunt motor, its output characteristics are adaptable for a wide variety of power requirements.

FEATURES

ELECTRICAL

- Alnico field magnets
- No field losses
- Low starting current
- Reversible with change of polarity
- Low RF interference
- Armature windings varnish impregnated and baked

MECHANICAL

- Completely enclosed
- Mounting in any position
- Aluminum end brackets
- Laminated pole pieces
- Stainless steel shaft
- Rotation on ball bearings
- Commutator mica insulated

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Oct. 12–14. Fall Meeting, Buffalo, N. Y. ELECTROCHEMICAL SOCIETY, Colin G. Fink, secretary, Columbia University, New York 27, N. Y.

Oct. 16–18. Fifty-Sixth Semi-Annual Fall Conference, New York, N. Y. SOCIETY OF MOTION PICTURE ENGINEERS. W. C. Kunzmann, vice president, Hotel Pennsylvania, New York, N. Y.

Oct. 16–19. Twenty-Fifth Annual Meeting, Cleveland, Ohio. AMERICAN WELDING SOCIETY, M. M. Kelly, secretary, 33 West 39 St., New York 18, N. Y.

Oct. 19–21. Electronic Parts and Equipment Industry Conference, Chicago, Ill. PARTS DIV., RMA; ASSOCIATION OF ELECTRONIC PARTS AND EQUIPMENT MANUFACTURERS; EASTERN DIV., SALES MANAGERS CLUB; and NATIONAL ELECTRONICS DISTRIBUTORS ASSOCIATION; H. W. Clough, chairman, PO Box 5070-A, Chicago 80, Ill.

Oct. 20. Annual Meeting, New York, N. Y. ENGINEERS COUNCIL FOR PROFESSIONAL DEVELOPMENT, S. L. Tyler, secretary, 29 West 39 St., New York 18, N. Y.

Oct. 20–21. Twenty-Ninth Annual Meeting, New York, N. Y. OPTICAL SOCIETY OF AMERICA, Arthur C. Hardy, secretary, Massachusetts Institute of Technology, Cambridge 39, Mass.

Nov. 2–3. National Time and Motion Study Clinic, Chicago, Ill. INDUSTRIAL MANAGEMENT SOCIETY, C. S. Becker, vice president, 205 West Wacker Drive, Chicago 6, Ill.

Nov. 9–10. Fall Meeting, Dayton, Ohio. INSTITUTE OF THE AERONAUTICAL SCIENCES, Robert R. Dexter, secretary, 1505 RCA Bldg. West, Rockefeller Center, New York 20, N. Y.

Nov. 13–14. Rochester Fall Meeting & War Radio Conference, Rochester, N. Y. ROCHESTER FALL MEETING COMMITTEE, Virgil M. Graham, chairman, PO Box 750, Williamsport, Pa.

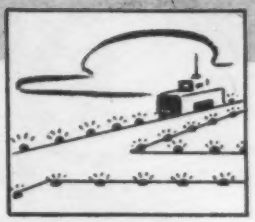
Nov. 13–14. Annual Fall Convention, New York, N. Y. SOCIETY OF THE

Your Airport may have all of these

RUNWAYS

SERVICE

HANGARS



LIGHTS

But it still is not a modern airport serving your community to best advantage, if it does not have radio facilities

Essentials of a modern airport, in the order of their importance, might be listed this way:

1. Adequate all-weather runways.
2. Sufficient service for normal requirements.
3. Hangar space.
4. Lights.
5. Control tower.
6. Radio navigational facilities.
7. Weather information.
8. Terminal facilities including restaurants, taxi service, etc.
9. Accessible location.
10. Safe approaches from all directions.

and — an able, adequately paid airport manager who can make the fullest use of his facilities in the interests of the public, flyers and the airlines.

Our job—that of RADIO RECEPTOR—is the provision of radio facilities for navigation—for traffic control—for communication. Chances are RADIO RECEPTOR ranges — supplied to the CAA — may guide the planes to your airport. Let RADIO RECEPTOR traffic control equipment continue the job and bring them down to the runways and up to the gates.

Competent counsel on airport traffic control radio now available—equipment supplied when conditions permit. *Plan* now—*purchase* later.

Send for our informative 16-page, 8x11 publication

"HIGHWAYS OF THE AIR"

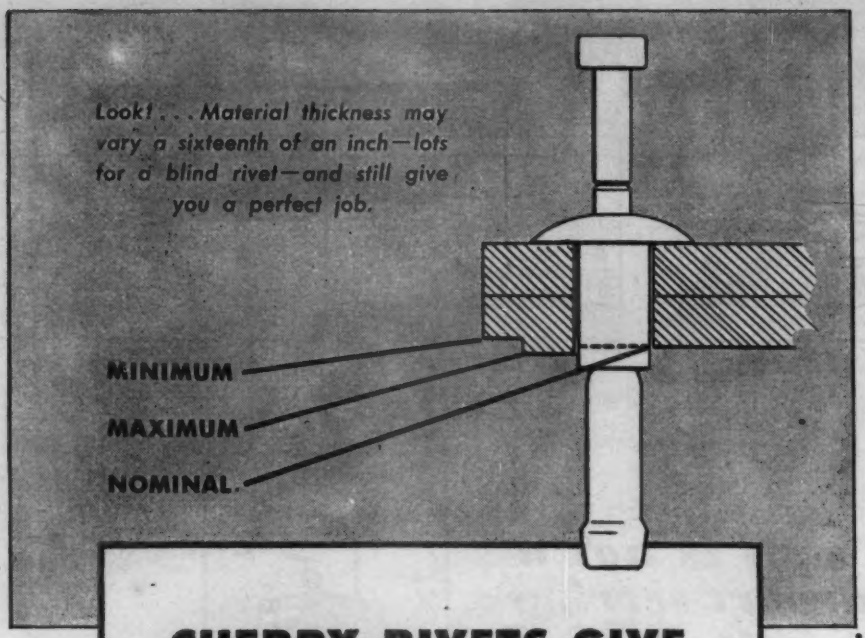
which discusses radio navigation and traffic control in all its phases, military and civilian—past, present and future. Free to those writing on their letterhead.

RADIO RECEPTOR COMPANY, Inc.

251 WEST 19th STREET **NEW YORK 11, N.Y.**

Airway and Airport Radio Equipment • Communications Equipment • Industrial Electronics • Electronic Power Generators

SINCE 1922 IN RADIO AND ELECTRONICS


Look! . . . Material thickness may vary a sixteenth of an inch—lots for a blind rivet—and still give you a perfect job.
MINIMUM
MAXIMUM
NOMINAL

CHERRY RIVETS GIVE GENEROUS TOLERANCES IN GRIP LENGTH!

Don't hesitate to use blind rivets just because the materials used may vary slightly in thickness in different areas. Use Cherry Rivets. As long as you stay within the generous tolerances specified, you'll get a good finished job.

The Cherry Rivet head (patented): (1) slips easily into the tool, (2) provides a positive grip, (3) keeps the rivet parts assembled as a unit.

CHERRY RIVETS, THEIR MANUFACTURE AND APPLICATION ARE COVERED BY U.S. PATENTS ISSUED AND PENDING

Cherry Rivet Company
LOS ANGELES, CALIFORNIA

Here's a handbook on Cherry Rivets. Read it and find out how tough jobs can be made easy with Cherrys. Write for Handbook A-43 to Dept. A-120, Cherry Rivet Company, 231 Winston Street, Los Angeles 13, Calif.

PLASTICS INDUSTRY, C. S. Shoemaker, meeting chairman, Dow Chemical Co., 30 Rockefeller Plaza, New York 20, N. Y.

Dec. 7–8, First Annual Conference, New York, N. Y. TELEVISION BROADCASTERS ASSOCIATION, Will Baltin, secretary, 500 Fifth Ave., New York 18, N. Y.

D.C. BIAS

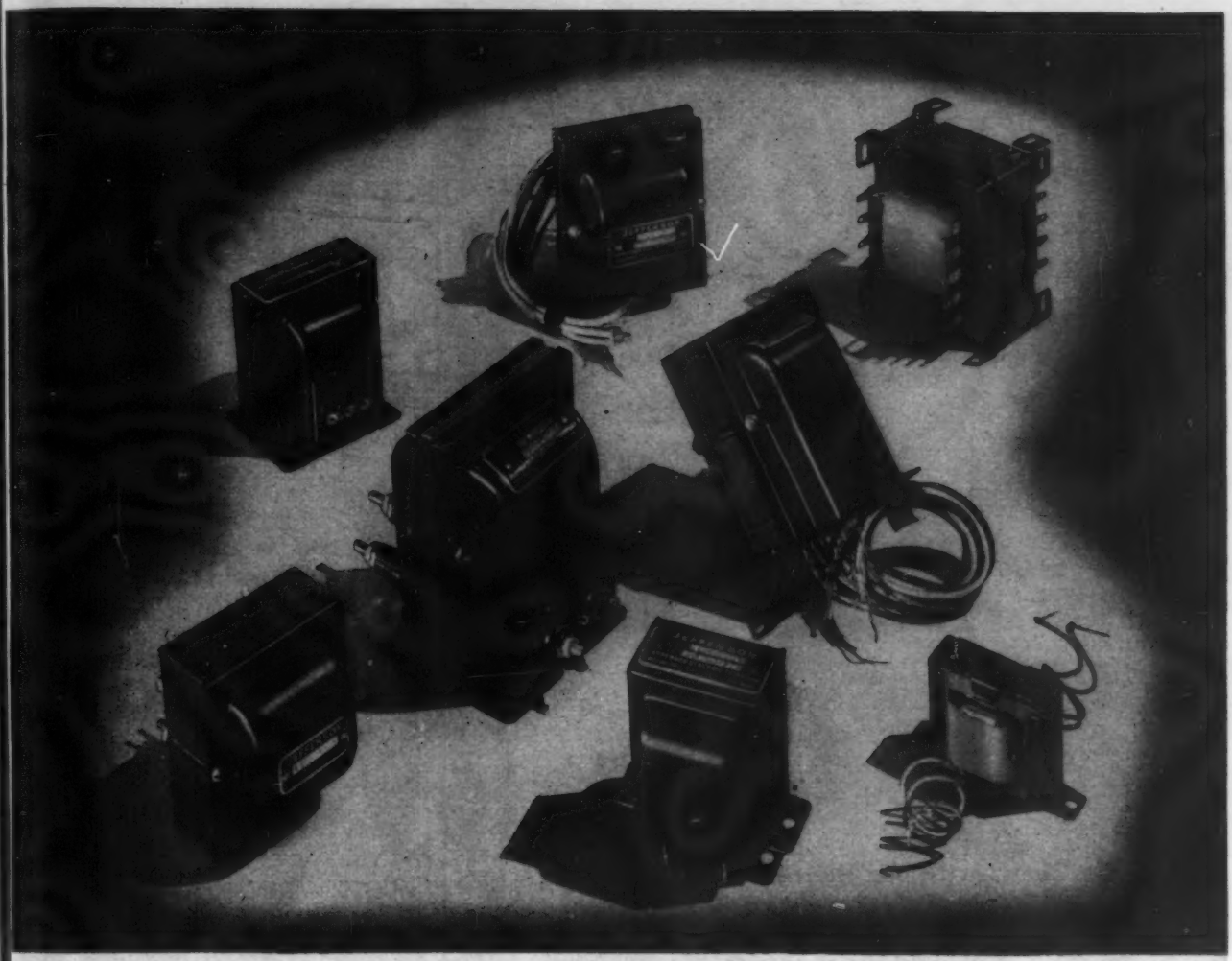
CIVILIAN RADIO. Production of civilian radios will be resumed after Germany surrenders, and not before such time, the Radio Industry Advisory Committee was told by leading WPB officials at a recent meeting in Washington.

These officials told the committee that the radio-radar production program for 1944 must continue upward through December and about 16.4 percent above the July output rate. Army and Navy officials concurred in this estimate of over-all increase during the remainder of the year.

FORESTRY OPERATION. With several provisos, FCC has amended its rules so a licensed operator who is the holder of a radiotelephone or radio-telegraph first or second class license may be on duty as the operator of one or more forestry stations licensed in the name of the same person, municipality, or state, at any location within the reliable daytime communication range of each such station in lieu of the transmitter locations or control point(s) during actual operation of the transmitting apparatus employing telephony.

UPHILL PRODUCTION. The forthcoming months will be more critical than any period previously faced by the electronic industry, and as a consequence the industry and WPB must effect the maximum cooperation on all problems, Ray C. Ellis, director of WPB's radio and radar division, recently advised the Industrial Instrument Industry Advisory Committee.

Reasons for the need of closer cooperation include problems of cancellation of contracts, reconversion, and labor which must be anticipated, he said. Commenting on the overall electronic industry production rate, Mr. Ellis pointed out that July, 1944, showed an increase of



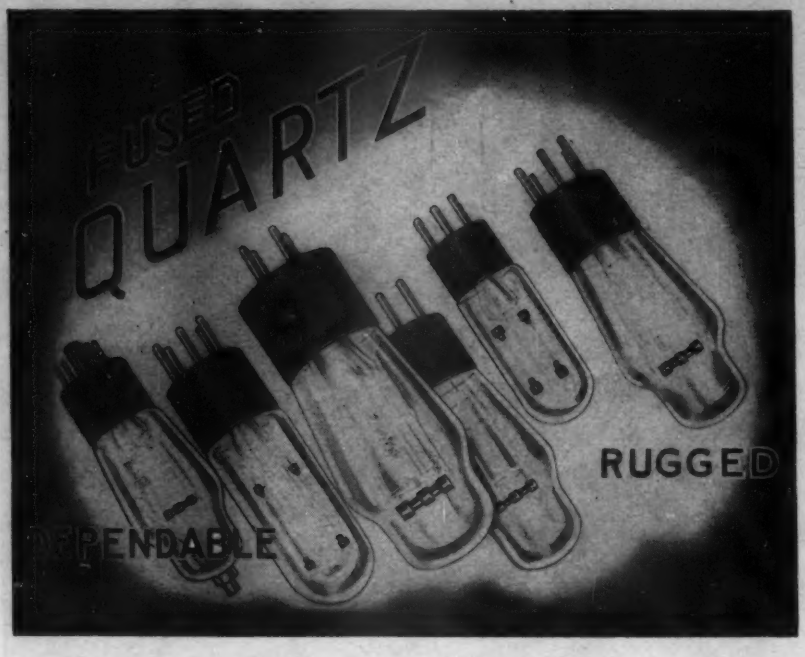
Quality in Quantity

WITH COMPLETE control of the design, selection of all materials, and methods of manufacture of all parts to the final assembly, inspection and delivery,—Jefferson Electric Transformers are laboratory correct whether required in small lots or hundreds of thousands.

War-time demands have further emphasized the ability to maintain high uniform standards of quality on a mass production basis. Under the stimulus of War effort, advanced types of machinery, and improved manufacturing technique, you can count on still better Jefferson Electric products for your post-war needs. Consulting now with Jefferson Electric transformer engineering specialists will save time for you later . . . JEFFERSON ELECTRIC COMPANY, Bellwood (Suburb of Chicago), Illinois. *In Canada:* Canadian Jefferson Electric Company, Limited, 384 Pape Avenue, Toronto, Ontario.

JEFFERSON ELECTRIC

TRANSFORMERS



INSULATORS

are a "Main factor" of the high power electronic tube. Quartz is the best electrical insulator known to science. Many other qualities make it ideal for the job. . . . Not subject to thermal shock. Non hygroscopic. High surface resistance. Shaped to specification.

ULTRA VIOLET LAMPS (quartz mercury arcs)

HYDROGEN ARCS IN QUARTZ

FUSED QUARTZ ROD,

TUBING, PLATES and SPECIAL SHAPES

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CHEMICAL & MANUFACTURING CO.

Dept. E-11 **NEWARK 5, N. J.**

approximately 16.4 percent over July, 1943. Production rose five percent in June, but was still four percent behind schedule in July, largely because of a 60- to 90-day lag between the new design on the drawing board and final assembly of the parts.

Serious manpower shortages exist in the production of certain component parts for signal equipment, such as dry-cell batteries and transformers. About 22,000 new workers will be needed in key electronic plants between now and the end of the year, WMC estimates, and an additional 12,000 a month will have to be found for replacements at the current rate.

About half the present workers are women, according to WMC, and that percentage can be stepped up to two-thirds if they can be recruited. Chief difficulty in adding to the labor force in this field, WMC points out, is that most of the plants center in labor shortage areas—around Chicago; near Philadelphia and Newark; and in the Buffalo, Syracuse, and Schenectady areas.

MORE BATTERIES. Demand for batteries, according to the Signal Corps officers who are charged with the duty of procuring all batteries for all the armed services, is still sharply on the upswing. Deliveries of all types of batteries have increased about two-thirds since the beginning of this year but monthly rates must be increased another 40 percent. The current monthly production of battery cells runs close to a hundred million, which is still far short of what is desired.

STATION SALES. FCC has asked Congressional direction as to the policy it should follow in passing on the sale of radio stations where the sales prices are far in excess of the going-concern and physical-property values of the stations and appear to involve considerable compensation for the radio frequencies themselves.

In identical letters to Senate Interstate Commerce Committee Chairman Burton K. Wheeler and to Rep. Clarence Lea, Chairman of the House Interstate and Foreign Commerce Committee, FCC chairman James Lawrence Fly suggested the "tremendously high prices" which radio stations command in the present market indicates the

And now we add *Embossing* to make CLOTH serve more people . . . more ways . . .

Embossing is a surface treatment generally applied to coated cloth to secure a decorative effect or to simulate a naturally irregular surface. One of the most common forms of embossed treatment copies various leather finishes and many so-called "imitation leathers" have all of the appearance value and much of the durability of leather and, in addition, are waterproof, non-porous and uniform. Various coarse fabric textures are embossed as well as all-over designs. A combination of embossing with printing (color on high spots) produces unlimited pleasing contrasts.

EMBOSSING

Under pressure a relief pattern is produced in the plastic coating. The cloth structure is in no way damaged or weakened. For certain industrial uses embossing may create lines or marks of functional value.

CURRENT HOLLISTON PRODUCTION includes COATED AND IMPREGNATED FABRICS . . . INSULATING CLOTH BASE . . SEPARATOR CLOTHS rubber, starch-filled, glazed. TRACING AND BLUE PRINT CLOTHS white and blue, ink or pencil. MAP CLOTH, PHOTO CLOTH, self-adhesive. REINFORCING FABRICS. SIGN, LABEL AND TAG CLOTHS, waterproof to take any ink, meet any inking problem. BOOK-BINDING CLOTHS. SHADE CLOTH, impregnated waterproof, opaque, translucent or light proof.

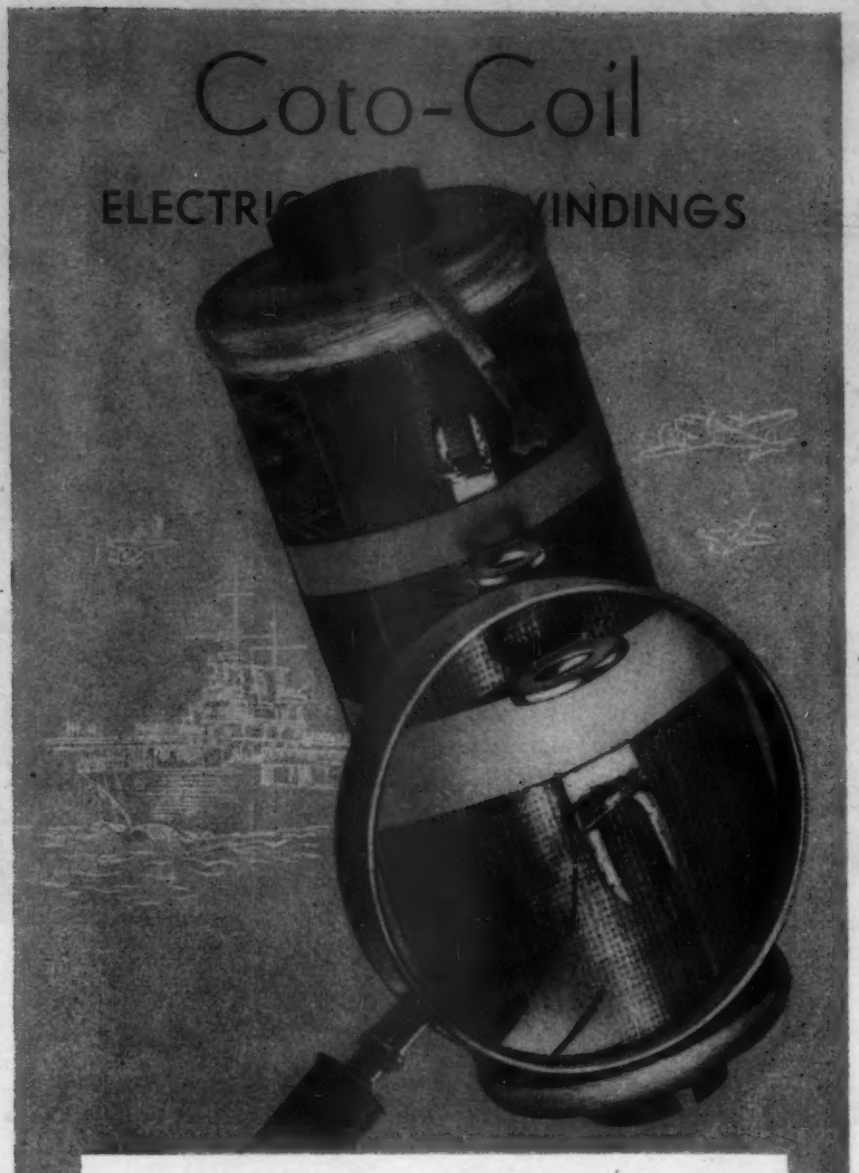
We urge you to consider CLOTH, and invite you to consult with us concerning possibilities and developments for your specific requirements.

The Holliston Mills, Inc.

PROCESSORS OF CLOTHS FOR SPECIAL PURPOSES

NORWOOD, MASSACHUSETTS

Sales Agents in Principal Cities



INSIDE STORY

- The destiny of a "flat-top" depends on this little soldered connection in a coil winding.
- And so, across the entire fighting front . . . in tanks and ships and in planes . . . the lives of our fighting men, the success of their missions and the safe return of equipment permits of no compromise in quality.
- Windings by Coto-Coil fire remote guns . . . release a single bomb or a salvo. The applications are countless . . . many cannot be told, but the importance of never failing dependability is apparent to all.
- Whether you build equipment for the armed services or for industry, you cannot afford to use any coils but the best.

COIL SPECIALISTS SINCE 1917

COTO-COIL CO., INC.

65 PAVILION AVE. PROVIDENCE 5, R. I.

sellers may be profiting from their lien on a radio frequency which they have been authorized to use under the Communications Act of 1934, but whose ownership under the Act is reserved to the public.

RADIO-PHONOGRAPH PRICING. The price schedule that previously governed manufacturers' maximum prices for consumer-type radio receivers and phonographs has been revoked, and the articles transferred to coverage by the regulation affecting most other consumers' durable goods, the Office of Price Administration has announced.

This transfer to coverage was made because the previous regulation covering the articles dealt only with price control problems that were acute in 1942, before civilian production was completely shut off, and is not suited to present conditions. In particular, it does not provide a method for pricing new models of radio receivers and phonographs.

EDUCATIONAL BROADCASTING. FCC has adopted a new application Form 340, to be used when filing an application for construction of a noncommercial educational broadcast station. This form supersedes Form 309 and supplemental Form 313 but Form 309 continues to be used for several classes of broadcast stations other than standard.

Form 340 is expected to be more convenient to applicants desiring noncommercial educational broadcast facilities, and at the same time the form will supply the Commission with additional information concerning the service planned and the technical equipment proposed to be installed. The new application form now available will be used by the many nonprofit educational agenies planning the construction of f-m broadcast stations for the advancement of their educational work and the transmission of educational and entertainment programs to the general public.

REGULATIONS FOR RADIO SERVICEMEN. Information has been compiled by domestic and foreign branch of the radio and radar division of WPB to guide radio repairmen now in business as well as exrepairmen and men discharged from military service. In order that they may

We time the Punch with *Electrons*

. . . so that it "lands" with the *extra* force needed to fill the die.

In this Reed-Prentice Plastic Injection Moulding Machine, granulated plastic material is forced through a heated cylinder into the die at continuous high speed, under high pressure. Photoswitch Electronic Timer T15U actuates controls within the hydraulic system that provide maximum pressure, *at the exact* instant, with the *fractional second timing required* to complete the injection stroke.

Why Electronic Timing is the Best Answer for Split-Second Repeat-Cycle Accuracy

Photoswitch Electronic Timers function with split-second accuracy . . . without fatigue . . . frictional wear . . . or inertia. Electronic operation eliminates clockwork, springs, mechanical clutches . . . all moving parts subject to wear and failure . . . provides consistently accurate control without danger of speed-up or slow-down, and with extremely long life assured. Photoswitch Electronic Timers are used extensively to initiate automatic operation of precision production grinders, millers, profilers and other machine tools; to insure maximum safety and efficiency in X-ray equipment; to provide split-second control in welding, molding, spraying . . . and to afford the high degree of accuracy needed in process control.

9-9

Write to
PHOTOSWITCH, INCORPORATED
Cambridge 42, Massachusetts
for Bulletin 900-A.

PHOTOSWITCH
INCORPORATED

PHOTOELECTRIC AND ELECTRONIC CONTROLS FOR EVERY INDUSTRIAL PURPOSE

BUILT LIKE A BATTLESHIP

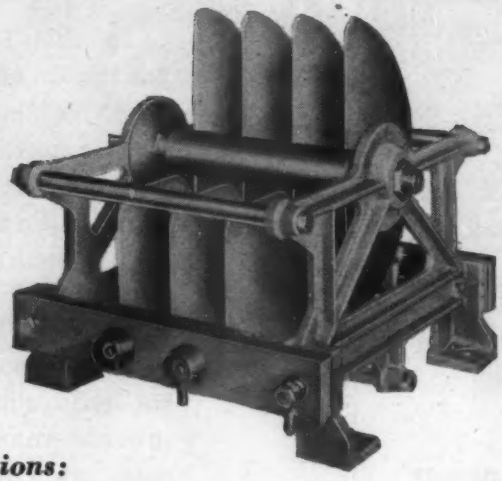
. . . and just as indestructible

Discriminating radio transmitter manufacturers believe that the very best components are not too good for their high power equipment.

Such manufacturers are using Cardwell condensers typified by the Type WX-95-VS heavy duty transmitting capacitor (illustrated).

The customers of these manufacturers know that a component, embodying master craftsmanship of such superior quality, is the finest money can buy and, indeed . . .

The Standard of Comparison



Specifications:

Type WX-95-VS
Capacity—100—42 mmfds.
Airgap—1 inch.
Peak Voltage—20,000 volts.
Size—15½" x 15½" x 13¾" long.
Frame—Cast aluminum end plates with brass tie rods.
Rotor—⅛" brass plates pressed and soldered into solid brass barrel.
Stator—⅛" brass plates pressed and soldered into massive brass stator blocks; equipped with electrostatic shields, on blocks and stator studs, to minimize corona losses.
Rotor Contacts—Laminated phosphor bronze self-cleaning brush.
Finish—Polished lacquered brass—End Castings satin finish aluminum, lacquered.
Bearings—Ball thrust rear—shoulder front bearing.
Shaft Extension Diameter—½ inch.
Insulation—Mycalex.

STANDARD OF COMPARISON
CARDWELL CONDENSERS
THE ALLEN D. CARDWELL MANUFACTURING CORPORATION
81 PROSPECT STREET BROOKLYN 1, N. Y.

know how to obtain necessary materials to carry on or enter into the radio repair business, they will be guided by specialists in the field service branch of regional and district offices who are familiar with WPB orders and the problems of civilian radio in wartime.

Summaries of applicable regulations include those pertaining to creation of an inventory, replacement of components and tubes, and purchase of tools and test equipment.

Another pertinent ruling is a recent issue by OPA (Office of Price Administration) which has restricted gasoline-rationing mileage to those radio repairmen who are working on government- or government-agency-equipment.

COMMUNICATIONS FELLOWSHIPS. Training of Latin American engineers in the regulatory and operating procedures of communications in the United States is the aim of a program sponsored by the State Department which has allocated $10,000 to FCC for such work. Rules and regulations have been formulated by FCC to govern the awarding of fellowships to applicants from other American republics.

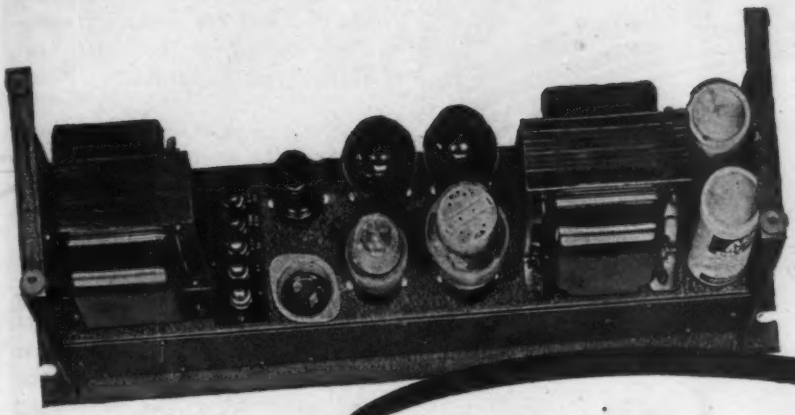
Fellowships shall be of the interne-training type which may include orientation in FCC offices; instruction in the engineering departments; and training in monitoring stations of the Commission; besides visits to other government agencies, private communication companies, and other background sources. Rules which have been established cover qualifications, award of fellowships, allowances, and expenses.

BUSINESS NEWS

ELECTRONIC MANUFACTURERS ASSOCIATION has been formed in New York, N. Y. Membership is drawn from companies active in the metropolitan and nearby areas.

MILWAUKEE INDUSTRIAL DESIGNERS has moved to new quarters at 744 North Fourth St. Milwaukee 3, Wis.

INTERNATIONAL BUSINESS MACHINES CORP. and GENERAL ELECTRIC CO. have collaborated on a proposed network joining Washington, New York, and Schenectady and which will operate in the region be-



HARVEY 106 PA
200 to 300 VOLTS

HARVEY
OF CAMBRIDGE

New
HARVEY 206 PA
500 to 1000 VOLTS

for REGULATED POWER SUPPLY

If you're looking for a dependable, controllable source of laboratory D.C. power for operation with pulse generators, measurement equipment, constant frequency oscillators, amplifiers and other equipment requiring a constant flow of D.C. voltage, it will pay you to get in touch with Harvey of Cambridge.

The Harvey Regulated Power Supply 106 PA will meet your every requirement in the lower voltages. It has a D.C. output variable from between 200 to 300 volts that is regulated to *within one per cent.*

The New Harvey Regulated Power Supply 206 PA is for higher voltages. This latest Harvey development operates in two ranges 500-700 at ¼ of an ampere and 700 to 1000 at .2 of an ampere. Both ranges have accurate regulation to *one per cent or better.*

Whatever your requirements, one of these Harvey Regulated Power Supply units will meet them with efficient, dependable performance.

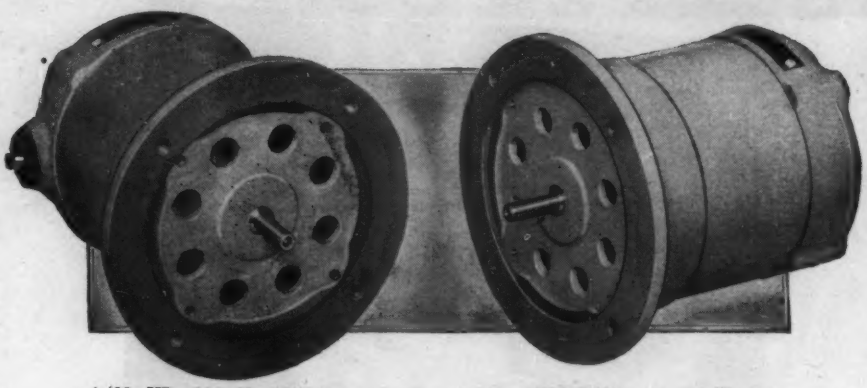
We'd be happy to supply you with complete information on either or both of them.

HARVEY
OF CAMBRIDGE

HARVEY RADIO LABORATORIES, INC.
439 CONCORD AVENUE • CAMBRIDGE 38, MASSACHUSETTS

OHIO

MOTORS for ELECTRONIC APPLICATIONS



1/30 HP—115 V—60 Cy.—A. C.—1 Ph. 1725 RPM. C. C. Flange Mounting. Ball Bearing.

•

Cut shows one of many types and sizes of Ohio Motors designed for driving Electronic Devices.

RANGE

1/100 to 2 HP.—A.C.
1/100 to 1 HP.—D.C.
1/100 to ¼ HP.—A.C. Synchronous.
1 to 100 oz. ft. A.C. Torque.
Shell type motors for built-in applications to 4 HP.—D.C. and to 7½ HP. —A.C.
All usual voltages and cycles.

What is your problem?

THE OHIO ELECTRIC MANUFACTURING CO.
5908 Maurice Avenue Cleveland 4, Ohio

tween 1900 and 2300 Mc. Facilities are to be used for relay purposes, possibly including television, fm, radiotype, and facsimile.

MERIT COIL & TRANSFORMER CORP. has completed a new plant at Chicago, Ill., and will combine general offices with production facilities there.

AMERICAN TELEPHONE & TELEGRAPH CO. and SOUTHERN BELL TELEPHONE & TELEGRAPH CO. have been given FCC permission to spend an estimated $6 million on coaxial lines between Atlanta, Ga., and Dallas, Tex.

PENNSYLVANIA RAILROAD has planned to equip its Harrisburg main-line division with radiotelephone equipment in 300 freight and passenger locomotives and 90 cabooses. Cost has been set at $1 million.

DEJUR-AMSCO CORP. has completed plant No. 2 in Long Island City, N. Y. Facilities cover 75,000 sq ft.

NATIONAL RADIO INSTITUTE, Washington, D. C. has completed 30 years of service to the industry.

PRESS WIRELESS INC. has arranged to move its executive offices from Chicago to 1475 Broadway, New York, N. Y.

RCA VICTOR DIV., RADIO CORP. OF AMERICA will introduce the first electron microscope into the laboratories of Australia for war production research. It will be delivered to the Council for Scientific and Industrial Research.

FAIRCHILD CAMERA & INSTRUMENT CORP. has been assigned an approved quality-control rating by USAAF. This means that duplicate Army inspection during detail fabrication will be eliminated and the company will be given full responsibility.

RCA VICTOR DIV., RADIO CORP. OF AMERICA, has finished its millionth Type X crystal which was placed in a gold-plated container for ceremonial purposes.

PRATT INSTITUTE, Brooklyn, N. Y. has announced a forthcoming series of tuition-free ESMWT courses including introduction to radio, radio

For Your Postwar Needs in Connectors and Related Units

If your postwar plans will involve coaxial cable connectors, cable plugs or special design parts of similar nature—we invite your consideration of our products and facilities.

Besides offering a comprehensive line of standard units, Connector Division possesses a unique engineering skill and knowledge in this field that may prove of valuable help and economy to you.

INTRODUCING MINIATURE BATTERY PLUGS

(Illustrations are actual size)

Anticipating the trend to midget devices, IRC presents this new, easy-grip battery plug. Pins are firmly imbedded in molded bakelite to insure positive contact. Side-positioned lead entries reduce strain on soldered connections. Fitting all miniature batteries, these plugs should find wide application in many types of equipment especially in the radio, hearing-aid, medical apparatus, and appliance fields. Available in two-pin or three-pin models. Specifications and samples on request.

Write for Catalog

IRC

*CONNECTOR DIVISION OF

INTERNATIONAL RESISTANCE CO.

401 N. BROAD ST., PHILADELPHIA 8, PA.

*FORMERLY CONNECTOR CORPORATION

YOUR COPY IS READY FOR MAILING

This new 44 page book gives you the complete story of "SPRING-LIFE" BELLOWS

By engineers—for engineers—yet with information and illustrations so complete that all men engaged in manufacturing can gather a full knowledge of bellows and their functions.

This informative book tells all about "Spring-life" Bellows, including their characteristics, construction and applications, plus data charts and other valuable information to assist engineers in determining bellows requirements.

Also included in this book are illustrations and information pertaining to Cook Pressure Detector Switches, and an introduction to the Cook "MetaLastic" Division. This catalog will be sent to you immediately upon receipt of a request on your letterhead.

Remember, if you have an extremely urgent problem, wire or 'phone us, and we shall be pleased to quickly dispatch a field engineer from one of our district offices to assist you.

COOK ELECTRIC Company

2700 SOUTHPORT AVENUE • CHICAGO 14, ILLINOIS

construction and testing, elements of electronics, industrial electronics, and u-h-f techniques.

GENERAL ELECTRIC CO., Schenectady, N. Y., has launched a program which will eventually see all the parts of its electronic activity centered in an industrial development on the outskirts of Syracuse, N. Y. Construction of the plant has been planned for the end of wartime.

KANSAS CITY & SOUTHERN RAILROAD has completed an installation of two-way radiotelephone communication along its entire main-line 560-mile right of way.

RCA VICTOR DIV., RADIO CORP. OF AMERICA, has established a comprehensive re-employment program which will affect the 6000 former workers serving in the armed forces.

GALVIN MFG. CORP. has installed a two-way f-m radiotelephone communication system which gives instant contact throughout the entire length of the Panama Canal.

FORT WORTH ELECTRONICS CLUB has been organized by 19 charter members connected with local industries. Monthly meetings are scheduled.

DEFOREST'S TRAINING INC., Chicago, Ill., has listed twelve lectures which are to be given there between Sept. 20 and Dec. 6 on subjects related to industrial electronic engineering. Covered will be fundamentals, rectifiers, thyratrons, measuring, welding, motor control, phototubes, elevator control, x-ray, heating, and lighting.

CANADIAN NATIONAL RAILWAYS has made tests on two-way radio communication in the Montreal terminal area.

COOPER UNION, New York, N. Y., has scheduled a series of engineering courses for evening attendance starting Oct 2. Communications principles, advanced electric circuits, and electrical engineering for other than electrical engineering students are to be included.

NEARLY $9,000,000 worth of equipment would be needed if the FCC were to approve the applications for FM stations now on file.

DON'T LET OLD-FASHIONED RESISTORS CRAMP YOUR ENGINEERING STYLE!

The only Resistors wound with CERAMIC-INSULATED WIRE

INSULATION APPLIED BEFORE WIRE IS WOUND

A Major Resistor Improvement—*Not just a minor change*

Don't waste time engineering "around" the handicaps imposed by conventional resistors! Use Sprague Koolohms and get exactly what you want.

No power resistor can be one whit better than the insulation given its windings—and Koolohm ceramic insulation applied to the wire before it is wound gives you the maximum in this respect. Koolohms can be used safely up to their full rated wattage values. Their use of insulated wire permits larger wire sizes to be used, and guards against shorts and changed values. They give more resistance in smaller size, and are readily adaptable to almost any mounting style best suited to your production.

Standard Sprague Koolohms include 5- to 120-watt power types. Other Sprague Resistors include bobbin types, hermetically sealed power resistors, 5- to 150-watts, and meter multipliers. Write for new catalog—just off the press.

SPRAGUE ELECTRIC COMPANY, Resistor Division
(Formerly Sprague Specialties Co.)
North Adams, Mass.

ARMY E NAVY

SPRAGUE *KOOLOHMS

Totally Different . . . Outstandingly Superior

*T.M. REG. U. S. PAT. OFF.

NEW PRODUCTS

Month after month, manufacturers develop new materials, new components, new assemblies, new measuring equipment; issue new technical bulletins, and new catalogs

Vibration Fatigue Testing Machine

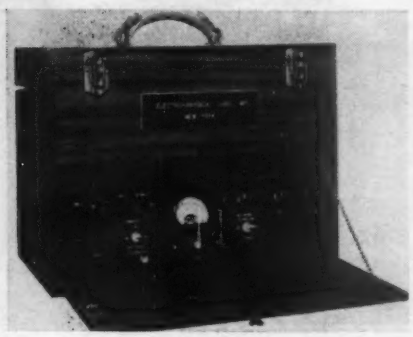
MODEL 10-HA IS a vibration fatigue testing machine which is designed to meet all requirements for a fatigue testing machine that will subject parts up to 10 lb in weight to vibration produced horizontally in simple harmonic motion. It has a range from 10 to 55 cps (600 to 3,300 vibrations per minute) which are increased and decreased automatically at a uniform rate.

A 4-page bulletin, No. 610, describes and illustrates Model 10-HA, as well as other vibration machines available from All American Tool & Mfg. Co., 1014 Fullerton Ave., Chicago 14, Ill.

Direct-Recording Electrocardiograph

INSTANTANEOUS, permanent, standard readings may be obtained with this inkless, direct-recording electrocardiograph (Type EPL) which is for use in electro-medical analysis and laboratory research. The instrument is compact, lightweight and portable, and requires no photographic processing. The recorder may be used in conjunction with other equipment for laboratory research. The electrocardiograph comes supplied with an amplifier and recorder which will give a graphic record between 0.1 and 80 cps at a sensitivity of 1 millivolt and 2 cm total deflection or a range from zero to 80 cycles for 60 millivolts and 2 cm deflection. A high speed writer can be supplied which will extend the frequency range to approximately 200 cycles. The phase correction is such that perfect square-wave response from 0.5 to 80 cycles is realized with the one-millivolt sensitivity connection.

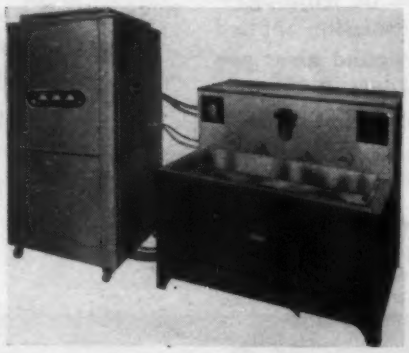
Electro-Physical Laboratories, Inc., 45 West 18 St., New York, N. Y.



Hardening and Quench Table

ILLUSTRATED IS A general-purpose, two-station hardening and quench table used in connection with high-frequency induction heating generators. The unit is suited to a wide variety of machine parts requiring surface hardening or localized heating. The table has quick-change coil connections so that jobs can be set up in 2 to 3 min to change a heating coil. The unit is flexible enough for low production requirements. An initial timer is provided to indicate the heating time for a new job or a new part and no stop watch or other means of timing is necessary. After the initial heating time has been determined, the timer can be cut out by means of a selector switch which is included in the assembly. A 3-stage timer automatically controls the heating and quenching positions of the cycle. A signal-type pilot light indicates heating is taking place.

Induction Heating Corp., 389 Lafayette St., New York 3, N. Y.



Secondary Frequency Standard

THIS SECONDARY FREQUENCY standard is crystal controlled with a hermetically-sealed MD cut dual-frequency crystal. It provides useful output up to 40 Mc at 1,000-kc, 100-kc and 10-kc intervals. It operates from 60 cps, 115 v line. The unit is housed in a sturdy metal cabinet.

The James Knight Co., Sandwich, Ill.

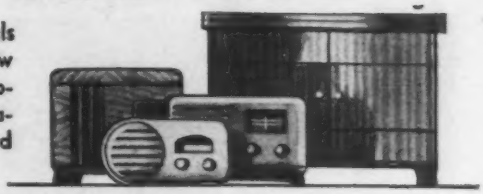
New Type of UHF Cables

NEW SIZES AND TYPES of solid-dielectric coaxial cables, used in uhf and radar equipment for the armed services, have been added to this manufacturer's line of cables. The cables are manufactured in five basic types:

Basic types of high-frequency cables. From left to right: coaxial air-spaced, spiral delay, twin-conductor, dual-coaxial, coaxial solid dielectric and armored coaxial cables

The ECA STORY

For almost a quarter of a century, most of the principals and personnel of ECA have had the opportunity to grow and expand with electronics. We've had experience producing many different types of highly specialized apparatus — including sound systems, test equipment and other electronic devices.

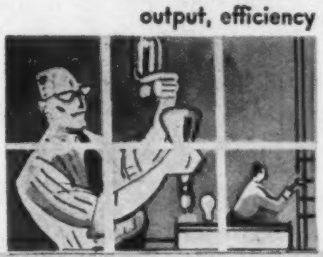


ECA engineers, designers and technicians are all accustomed to working to exacting laboratory standards. Rich in the fundamentals of radio and electronics, we can approach any problem with full confidence that the ultimate result will prove eminently satisfactory.

Naturally, during these crucial war years, our entire production is devoted to materials needed by the Armed Forces. Much of this equipment is of an extremely delicate and precise nature. All require maximum attention to design and construction to meet the standards of ECA as well as the government.

While devoting our working time 100% to war production, we have not forgotten home front activities. The Electronic Corporation of America is proud that each succeeding war bond drive has been over-subscribed, and we're equally proud of the blood donor award given to us by the American Red Cross.

Regularly at ECA, representatives of management meet with representatives of labor to discuss company policy, to fix production quotas, and to look after the needs of the individual worker. We have found that harmonious labor-management relations stimulate the output, efficiency and progress of our organization.



Under these splendid conditions will future ECA products be manufactured. Modern production techniques, trained personnel and precision laboratory and plant facilities will be utilized to produce superior ECA radios and electronic devices for home, industry and medical science. This, in effect, is the ECA story.

We shall be pleased to send you our new publication on..

What are the prospects for the future? How can America's vast industrial set-up be put to most effective use for a prosperous and abundant economy? What are the joint responsibilities of management and labor? Can small business survive? How can American business and industry achieve additional markets worth at least 25 billion dollars? Is the attainment of full scale employment a wishful dream or an actual possibility? The answers to these, and other vital questions, are supplied in "A Plan for America at Peace." Write for your copy . . . we'll gladly send it to you without charge or obligation.

ECA

ELECTRONIC CORP. OF AMERICA

45 WEST 18th STREET • NEW YORK 11, N.Y. WATKINS 9-1870

Listen in! UNCENSORED Commentaries on the News: — Johannes Steel, WMCA, New York, every Monday, Wednesday, Friday at 7:30 P.M.— William S. Gailmor, WHN, New York, Monday through Friday, at 9 P.M. — sponsored by the Electronic Corporation of America.

ECA will offer a new plan of distribution at the Electronic Parts and Equipment Industry Conference in Chicago. Be sure to talk to us about it.

a stitch in time

saves nine . . .

For certain uses there is no substitute for Mica. When substitution is attempted trouble follows.

When you think of MICA think of MACALLEN

the Macallen Company

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The first of these is called Coaxial. This line includes sizes from ¼ in. outside diameter up to and including cables over 1 in. in outside diameter. Standard designs include single and double-braided constructions with standard and armored covering.

Dual-coaxial lines have been developed to fill the need for parallel circuits having a high degree of electrical balance.

Twin-conductor lines, sometimes called "Twinaz" are balanced shielded pairs, usually somewhat smaller than dual-coaxial lines, and provide nearly as good an electrical balance.

For low capacitance requirements, there is available a line of coaxial air-spaced cables which can be made in any required length and which have capacitances as low as 8 micro-microfarads per foot.

The fifth type of cable is a spiral delay line which is for special test sets requiring lines with an appreciable delay or very high impedances. Some of these lines have in a 1-ft. length an electrical equivalent to that of 15 ft of coaxial cable.

All of these types are designed, generally, for 50 to 70 ohms impedance, and the type of cable selected is predicated by power requirement or power loss limitations.

A bulletin called "Intelin Coaxial Cable Impedance Nomographs" is also available.

Intelin Products Div., Federal Telephone & Radio Corp., Newark, N. J.

Alignment Tool

A NEW TOOL FOR precision alignment of padding capacitors in radio receivers and transmitters is Type TL-207 which is available from General Cement Mfg. Co., Rockford, Ill.

Shockproof Relays

THESE RELAYS ARE wound to specifications and are available in single or double pole. They have been subjected to vibration and other tests. A single relay measures 1⅝ in. wide, 2¾ in. long and 1½ in. high.

H. C. Evans & Co., 1528 W. Adams St., Chicago, Ill.

"They make everything in their line from the raw material to the finished product."

This sentence was written about a newsworthy feature of Connecticut Telephone and Electric operations nearly forty years ago. It has been important ever since.

This Division's facilities for complete fabrication of electrical parts and devices within its own plants are unusual. Because of them, the production of vital communications equipment, aircraft ignition devices and other urgently needed war material is being speeded. It permits important manufacturing economies. It gives us better control of the equipment we make. These things are important in war and peace alike.

CONNECTICUT TELEPHONE & ELECTRIC DIVISION

GREAT AMERICAN INDUSTRIES, INC.

MERIDEN, CONNECTICUT

TELEPHONIC SYSTEMS • SIGNALLING EQUIPMENT • ELECTRONIC DEVICES • ELECTRICAL EQUIPMENT • HOSPITAL AND SCHOOL COMMUNICATIONS AND SIGNALLING SYSTEMS • IGNITION SYSTEMS

THE AUTOMATIC ROBOT INSPECTOR

Television—as well as any other type of electronic equipment—can be checked with the ROTOBRIDGE . . . for wiring errors, for resistance and reactance values.

Versatile and vigilant, the Rotobridge is designed for intensive, 24-hour duty. With robot-like fidelity and exactness, the Rotobridge does what you want it to do, without hitch or hesitation. A 10% resistance tolerance at one point? A 25% capacity tolerance elsewhere? You get it with the Rotobridge . . . where and as you want it . . . accurately, automatically. And when the Rotobridge detects an error, it stops dead and instantly flashes a red warning signal—and keeps on flashing it until its human co-worker attends to the defect.

The Rotobridge can be put to work on several small sub-assemblies or on a complete set, involving as many as 120 circuits. Two or three of these robots working simultaneously are all you need to inspect a 30 or 40 tube set-up. And they'll do it in five minutes flat!

Write for complete details.

COMMUNICATION MEASUREMENTS LABORATORY

120 Greenwich Street New York 6, N. Y.

Thermoplastics Welding Machine

THIS MACHINE utilizes high-frequency current to weld many types of thermoplastics material. It is capable of welding about 35 ft per minute. The weld created is watertight, moisture-proof and air-tight. The machine itself resembles an ordinary sewing machine, but the welder can be modified to other physical forms and can be adopted as a step in the process of fabrication, or can be incorporated into other machines. The manufacturers state that the machine is not yet ready for distribution.

Richardson-Allen Co., 15 West 20 St., New York, N. Y.

Electron Tubes

AVAILABLE TO equipment manufacturers against WPB rated orders are the following new electron tubes:

1P29 is a gas phototube (violet-green sensitive) for colorimetric applications. Spectral response occurs over the spectral range from about 4000 to 8000 Angstroms, with maximum sensitivity at approximately 4200 Angstroms. Sensitivity at maximum response is 0.10 microamp per microwatt of radiant flux.

3B25 is a half-wave gas rectifier of a hot-cathode type. It is xenon filled and is ruggedly constructed to withstand severe vibration. It can be operated under conditions where ambient temperatures of −75 to +90 deg C are encountered. The tube will withstand a peak inverse voltage of 4000 volts and will deliver an average anode current of 0.5 amp.

6AL5 is a miniature twin diode featuring high perveance. It is for use as a detector in circuits utiliz-

SCREW MACHINE PARTS

FROM PHENOL FIBRE, VULCANIZED FIBRE, LUCITE, POLYSTYRENE OR ANY OTHER SPECIFIED PLASTIC MATERIAL

Producing Screw Machine Parts in large or small quantities is but one of our many specialized functions as specification fabricators. Here, in our modern plant, skilled operators fashion many such parts of all sizes and shapes from many different materials on precision machines which guarantee accuracy to extremely close tolerances.

Send us the specifications for your *next* screw machine requirements and let us prove to you that we can produce these parts *better* . . . *faster* . . . and *more economically!* We have a large stock of standard materials on hand at all times—all of which meet Army, Navy and Air Corps specifications.

Specification Fabricators of
GLASS BONDED MICA, PHENOL FIBRE, VULCANIZED FIBRE, RUBBER, ASBESTOS, CORK, CORPRENE AND OTHER MATERIALS

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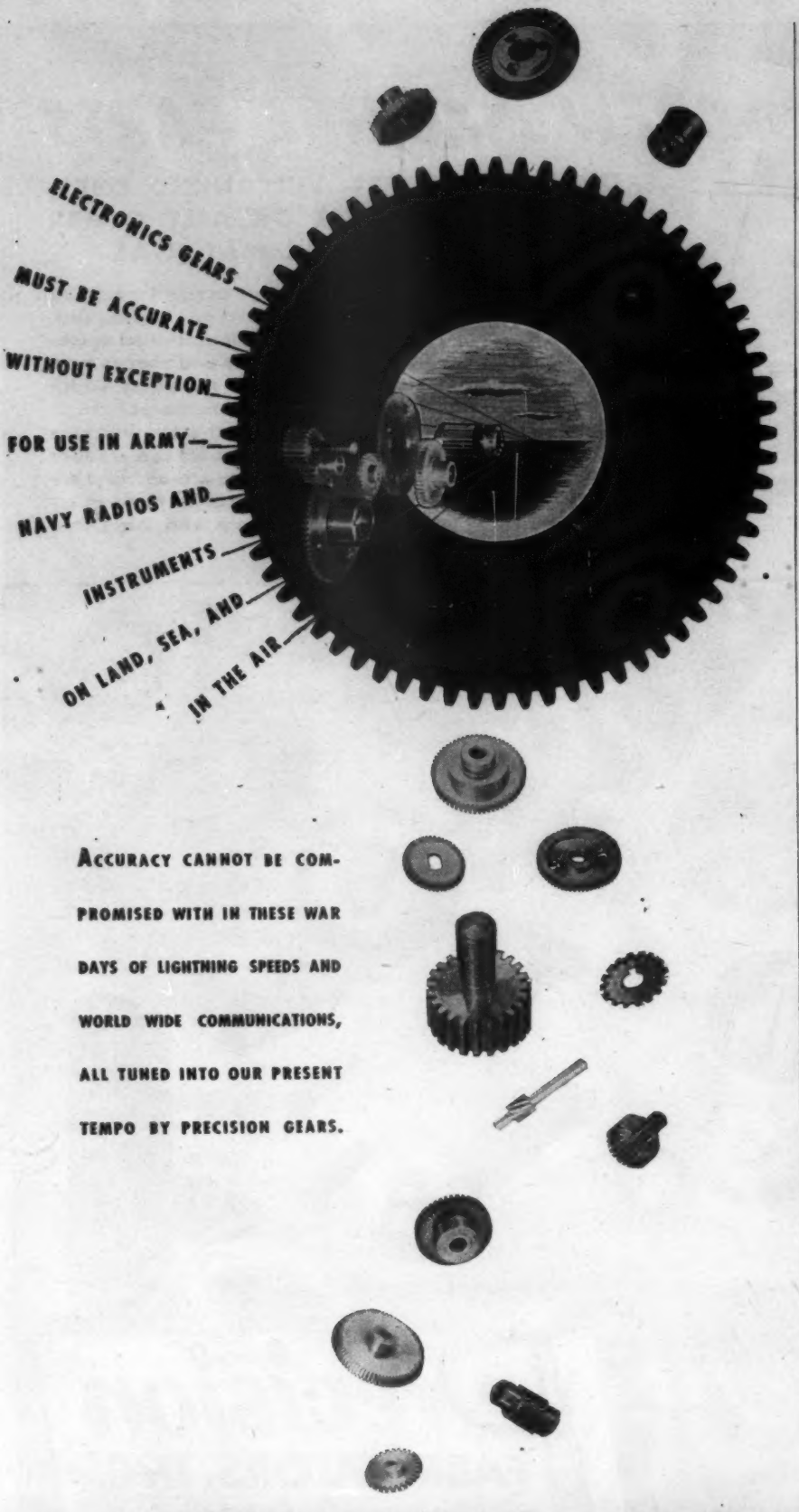


ACCURACY CANNOT BE COMPROMISED WITH IN THESE WAR DAYS OF LIGHTNING SPEEDS AND WORLD WIDE COMMUNICATIONS, ALL TUNED INTO OUR PRESENT TEMPO BY PRECISION GEARS.

Quaker City Gear Works
INCORPORATED
1910-32 North Front Street, Philadelphia, Pennsylvania

ing wide-band amplifiers. It has low internal resistance and will give an increased signal voltage from a low-resistance diode load. Each diode unit can be used independently of the other or combined in parallel or full-wave arrangement. This tube is an Army-Navy preferred type.

6F4 tube is an acorn triode of the heater type intended for use primarily as an oscillator at frequencies up to about 1200 Mc. Its features are high perveance and reduced lead inductance. At moderate frequencies (in class C oscillator service with 150 volts on plate) a single 6F4 tube is capable of giving a power output of approximately 1.8 watts. At 1200 Mc, and with 100 volts on plate, approximately 45 milliwatts can be obtained.

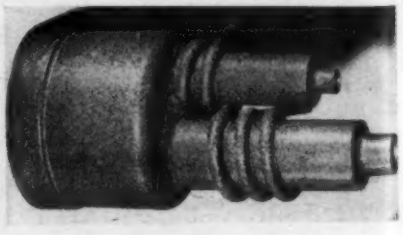
Radio Corporation of America, Harrison, N. J.

New Tubes

THREE NEW TUBE TYPES available include 6AK5, which is a sharp-cutoff r-f pentode; the 6AL5, a vhf twin diode; and the 6AQ6, which is a double-diode-triode. These tubes are being manufactured in accordance with WPB-authorized production schedules and are available from Hytron Corp., Salem, Mass.

Miniature Diffusion Pumps

DESIGNATED AS Type VMF, these small, compact metal pumps produce a vacuum of 10^{-6} mm of hg. They are for use with the new-style rotary exhaust machines in which a diffusion pump moves around with each tube, as well as for portable electron microscopes and similar apparatus. The pumps utilize a fractionating principle which does not require any liquid air trap. Heat transfer problems are eliminated by a boiler design. The units are normally cooled by water, but special air-cooled models are also available. The pumps are available in three



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ALL COMPONENTS ON TERMINAL BOARDS THAT USE DOUBLE BARRIER TERMINALS—EASY SERVICE

TERMINAL BOARDS VACUUM IMPREGNATED WITH FUNGICIDE VARNISH–MOISTURE PROOF

VINYLITE AND GLASS INSULATED WIRE– FUNGICIDE TREATED

PLATING AND PAINTING THAT WILL WITHSTAND NORMAL SALT SPRAY TESTS

OIL FILLED PAPER FILTER CONDENSERS– BY-PASSES PAPER, MOLDED IN BAKELITE

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FOR HIGHER THERMAL EXPANSION

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THE temperature coefficient of expansion of Chace Manganese Alloy No. 772 is twice as great as that of ordinary steel . . . considerably higher than aluminum, particularly at elevated temperatures . . . and far beyond that of any other strong alloy. Its expansion rate is independent of thermal treatment, and is not altered by cooling to -100° F. Thus it makes possible unusual differential expansion designs.

Chace Manganese Alloy No. 772 affords an unusual combination of useful engineering properties. It has an electrical resistivity about 60% higher than most resistance alloys in common use . . . a thermal conductivity only about 2% the value of copper . . . a vibration damping constant about 25 times greater than steel. It can be machined, stamped, drawn, extruded, and welded to itself or other metals.

AVAILABLE IN STRIPS SHEETS RODS AND SPECIAL SHAPES

Complete engineering and research facilities available . . . Bulletin No. A-942, giving detailed information regarding Chace Manganese Alloy No. 772, sent on request.

W. M. CHACE CO.
Manufacturers of
Thermostatic Bimetals and Special Alloys
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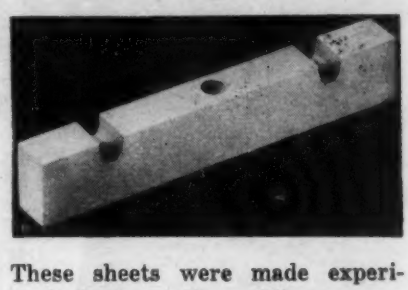
different sizes: VMF-6 measures 2¾ in. in diameter and 6 in. high; VMF-20 measures 5¼ in. in diameter and 9½ in. high; and VMF-10 which measures 7¾ in. high, 3⅞ in. wide, and weighs 25 lb. Other characteristics of type VMF-10 are: speed 10 liters/sec. at 10^{-4} mm hg; ultimate vacuum 1×10^{-9} mm hg with Octoil-S; required forepressure 0.125 mm hg; heater power 135 watts.

Distillation Products, Inc., Rochester, N. Y.

H-F Coil Supports Made of Nylon

PRINTLOID, INC., (91 Mercer St., New York 12, N. Y.) have issued a release in which they say that it is expected that when the supply of Nylon becomes sufficient for all needs, it will make its appearance in the form of rods, sheets and tubes, just as most other plastics. As a prelude to such production, DuPont recently produced a small quantity of Nylon in sheet form.

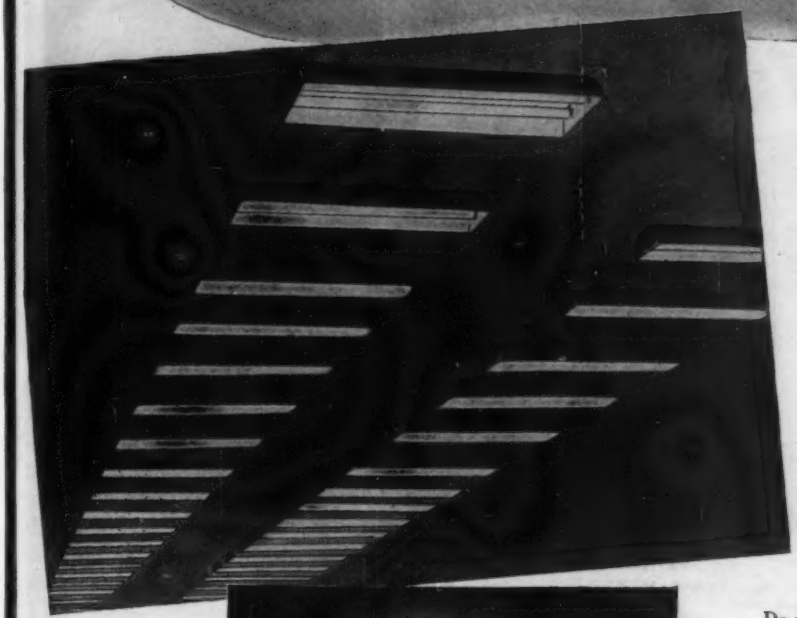


These sheets were made experimentally in small moulding presses by laboratory methods. Federal Telephone & Radio Corporation required a quantity of high frequency coil supports for some equipment they were producing. Printloid, Inc., fabricated these parts out of the new experimental sheets. Printloid will welcome inquiries concerning Nylon for electronic and other vital war uses.

Hermetically-Sealed Leads

THESE LEADS ARE constructed of Pyrex glass with Kovar electrodes and Kovar metal collars. They may be used in transformers, capacitors, coils, filters, and any other component requiring good lead-termination. A variety of standard sizes and shapes are available, and any shape or size can be furnished upon specification. The leads have high dielectric strength and are practically immune to thermal or me-

FIBERGLAS*
Electrical Insulation Tapes



Permit substantial space and weight savings in

FLUORESCENT *Ballast Coil* Design and Construction

• • •

Smaller, lighter, sign-lighting control and signal transformers also possible

Fiberglas tapes are available in tight and medium weaves, in all widths commonly required for insulating electrical products, in thicknesses of .003", .005", .007", .010" and .015".

Do you have a critical space problem—in ballast coils, transformers or other electrical equipment—where bulky insulations on the wire and around the coils are major factors in establishing the size and weight of your design? Then don't overlook the exceptionally low space factor of Fiberglas insulation—particularly tapes.

If space is at a premium—remember that a thinner inorganic Fiberglas tape will do the job of a thicker organic tape. And, too, Fiberglas tape will take much less space than equivalent inorganic materials. Because Fiberglas tape has superior tensile strength, it also permits a tighter, more compact wrapping of coils.

Besides low space factor and less weight in designed product, Fiberglas insulations have other advantages, for example:

• ***High thermal resistance.*** Although total effectiveness of insulation depends on impregnation, Fiberglas forms an insulating *base* which does not deteriorate from heat far above that encountered in electrical apparatus.

• ***No change with age***—of particular importance in standby equipment, or where equipment stands idle over long periods of time. The glass fibers do not deteriorate, even though moisture should penetrate the outer impregnation.

• ***Not affected by moisture or most acids.*** Again, total effectiveness depends on impregnation, but should impregnating varnish fail, moisture will not disintegrate the glass fibers—and often will permit motor to be dried out and run again.

WHAT IS FIBERGLAS?

Fiberglas is the trade name for glass in the form of fine fibers or filaments. These fibers are twisted into yarns, served on wire, woven into tapes and cloths, braided into sleevings, or twisted into cords—untreated or treated—to fill every electrical insulation need.

Fiberglas electrical insulations are immediately available in all the forms and sizes used in the electrical industry. For complete information, write *Owens-Corning Fiberglas Corporation, 1860 Nicholas Building, Toledo 1, Ohio; in Canada, Fiberglas Canada, Ltd., Oshawa, Ontario.*

FIBERGLAS

*T. M. Reg. U. S. Pat. Off.

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The Gothard Neon Lamp Pilot Light will burn continuously for approximately 3000 hours, as compared with the approximate 500 hour life of ordinary lamps. It operates on 110 volts and consumes only ¼ watt. The unbreakable lucite protective cap, designed and made for Gothard exclusively, provides perfect light dispersion of its warm neon glow in all directions. Lucite cap unscrews for lamp change. Bakelite socket. Polished and chrome plated jewel holder. 1" mounting hole. Colors: red, green, amber, blue and clear. Ask for complete information on this and wide range of the Gothard Lights.

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Star Steatite

is HARD!

Extremely rugged and tough, STAR STEATITE is the ideal material for use in high frequency electronic applications. It can be molded into exact shapes and machined to close tolerances. It resists great mechanical shock and extreme conditions of heat and humidity.

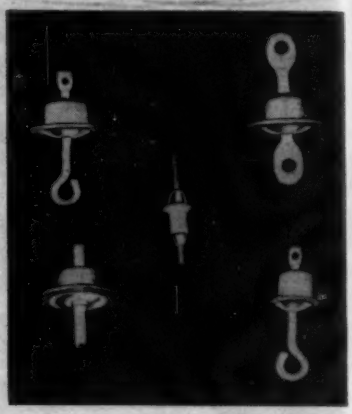
It has a very low power factor and dielectric loss. The Star product meets Government specifications.

After the war our great productive facilities will be at your disposal.

The STAR PORCELAIN COMPANY

ELECTRONICS DEPT., TRENTON, NEW JERSEY

chanical shock. They are completely free from absorption of moisture and humidity, and the surface of the glass insulator provides maximum water-shedding properties. The electrode and collar are easily soldered, brazed or

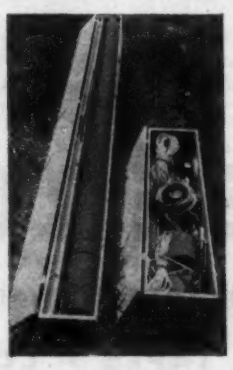


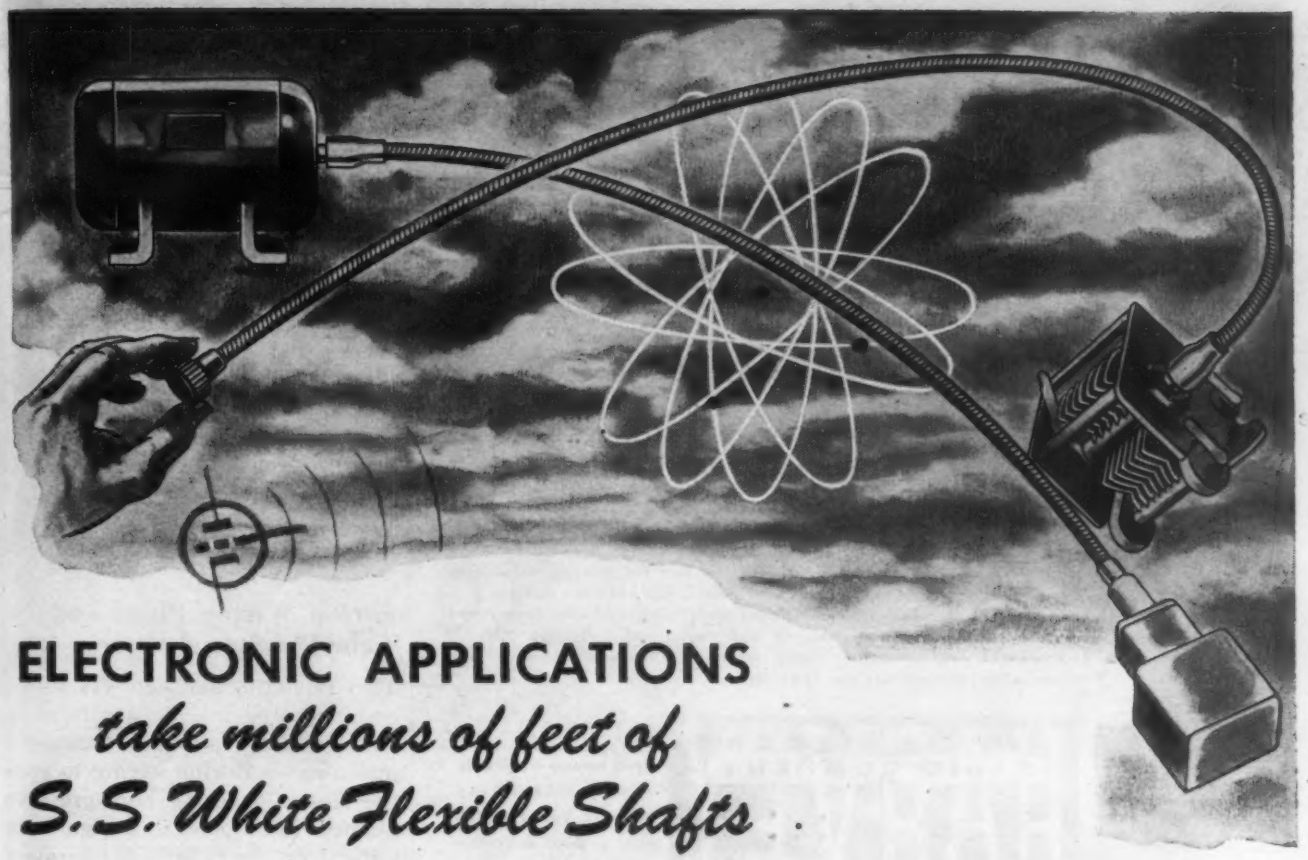
welded to a unit enclosure. Another feature claimed for these leads is that the use of Pyrex and Kovar form an absolutely gas and moisture-tight chemical bond, so that internal gas pressure may be maintained in units using them. This bond also minimizes the stress and strain of severe temperature changes.

Electrical Industries, Inc., 42 Summer Ave., Newark 4, N. J.

Resin-Bonded Plywood Tubing

PLYTUBE IS THE NAME of a plywood tubing fabricated from thin veneers and a thermosetting synthetic resin. According to the manufacturer, laboratory tests show that weight for weight, Plytube will carry a heavier load than steel tubing. Urea Formaldhyde is the material used as its bonding agent, though Phenol may also be used. Veneers, selected for their overall strength, are built up so that stress





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S. S. White power drive and remote control flexible shafts have long been the accepted standard in the aircraft, radio and electronic fields. Applications are many and varied, and war-born electronic developments have swelled their number.

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(3) Authoritative caliber of S. S. White engineering cooperation in applying flexible shafts to specific requirements.

When you need flexible shafts, or have a power drive or remote control problem remember it's . . .

S. S. WHITE FOR FLEXIBLE SHAFTS

For basic flexible shaft data write today for BULLETIN 43

S.S.WHITE INDUSTRIAL DIVISION

THE S. S. WHITE DENTAL MFG. CO.

DEPT. E 10 EAST 40th ST., NEW YORK 16, N. Y.

FLEXIBLE SHAFTS AIRCRAFT ACCESSORIES
MOLDED PLASTICS
MOLDED RESISTORS FLEXIBLE SHAFT TOOLS

the "Royal Family" of pickups, cutters, jewel points

AUDAX, now available through HARVEY, distributor of fine radio and electronic equipment, represents the ultimate in professional recording accessories. AUDAX Pickups are made with the unique "relayed-flux" principle so largely responsible for the sharp, clear-cut facsimile reproduction of Microdyne. Into the Pickups, as well as the Cutters and Jewel Points, has gone the delicate precision craftsmanship of masters of the trade. Long noted for its engineering and mechanical perfection, AUDAX equipment is used in radio stations, recording studios and wherever the performance requirements are exacting.

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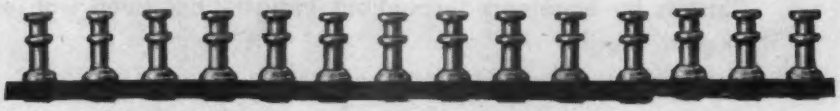
Write today for this valuable booklet which contains the answers to most questions in the field of sound reproduction, written by **Maximilian Weil**, leading authority on the subject.

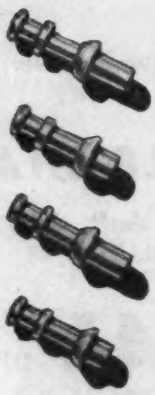
HARVEY RADIO COMPANY
103 WEST 43rd ST., NEW YORK 18, N. Y.

Upon receipt of suitable priority, HARVEY can promise you reasonably prompt deliveries of all AUDAX products.

ATTEN-SHUN!



C. T. C. TURRET TERMINAL LUGS are being ordered into action by more and more radio and electronics manufacturers. Here's why . . .



First—they're quick to apply. Just swage 'em to the boards and in a jiffy you have good, firm Turret Terminals.

Second—they save soldering time. Sufficient metal is used in their construction to provide strength, but not enough to draw heat and increase soldering time.

Third—quick delivery. Turret Terminal Lugs to meet a wide range of terminal board thicknesses are in stock.

Make C.T.C. **TURRET TERMINAL LUGS** *your* next order of the day. Write, phone or wire—

CAMBRIDGE *Thermionic* CORPORATION
439 CONCORD AVENUE · CAMBRIDGE 38, MASS.

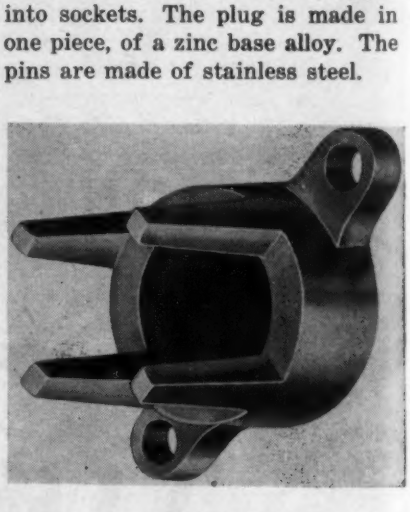
and strain in any direction acts upon the total columnar grain fibers of the veneer layers. Plytube is water, flame, splinter and rot proof. It has low electrical conductivity, is dimensionally stable under extreme temperature ranges, and is especially suitable for use in sub-zero weather. Among the many types of products made from Plytube are radio antenna masts which measure up to 90 ft high, and antennas and instrument covers for aircraft. The material is also available in any reasonable lengths of straight tubing. Inside diameters measure from $\frac{1}{2}$ to 18 in. Wall thicknesses measure from 0.05 to 0.50 of an inch.

Plymold Corp., Lawrence, Mass.

Socket Wiring Plugs and Tube Pin Straighteners

TWO PRODUCTS available from this manufacturer include a miniature socket wiring plug which is plugged into a socket during wiring to keep the socket soldering lugs properly aligned. The plug is designed to minimize tube failure due to glass

strains when tubes are plugged into sockets. The plug is made in one piece, of a zinc base alloy. The pins are made of stainless steel.



The tube pin straighteners for miniature tubes also have a zinc base alloy. The inserts are made of either hardened tool steel or of stainless steel.

Radio Accessory Div., Star Expansion Bolt Co., 147 Cedar St., New York 6, N. Y.

AN IMPORTANT NEW *Silver-Tungsten* CONTACT DEVELOPMENT

STACKPOLE MOLDED CONTACT TYPES

Silver-Graphite

Silver-Copper-Graphite

Gold-Graphite

Silver-Nickel

Silver-Molybdenum

Silver-Tungsten

Silver-Nickel-Molybdenum

Silver-Nickel-Tungsten

and dozens of special alloys.

One-third smaller by volume and with half as many parts! That, in brief, is the story of a circuit breaker produced by a leading manufacturer, and made possible by use of silver-tungsten contacts utilizing the recently developed Stackpole "FW 41" formula.

Thanks to the efficiency of this new contact material, the interrupting capacity of the circuit breaker in *its new small size* has actually been increased from 10,000 amperes to 15,000 amperes. On special test, it has interrupted 21,000 amperes without apparent damage!

FW 41 is but one of many Stackpole contact developments of outstanding importance to electrical equipment manufacturers who realize that contact problems do not stay solved—that today's "best" may well be obsolete tomorrow.

Stackpole engineers welcome the opportunity to study your particular contact application in the light of recent improvements, making their recommendations and suggestions accordingly. The Stackpole contact laboratory includes ample facilities for making contact tests under actual operating conditions.

STACKPOLE CARBON COMPANY, ST. MARYS, PA.

STACKPOLE

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Products of "MERIT" are passing the test

Complying with the most exacting requirements for precision workmanship and durable construction, MERIT has established its ability to produce in quantity and deliver promptly—

Transformers • Coils • Reactors • Electrical Windings of All Types for Radio, Radar and Electronic Applications.

Today these dependable MERIT precision parts are secret weapons; tomorrow when they can be shown in detail as MERIT standard products you will want them in solving the problems of a new electronic era.

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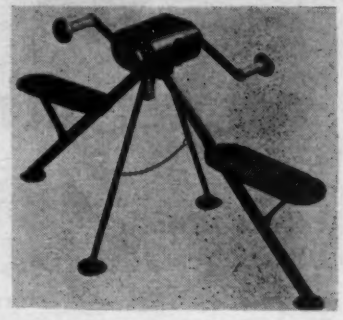
Railroad Dynamotors, and Hand Generators

THESE DYNAMOTORS are for use in communications systems for railroad use. They are designated as Magmotor series, and utilize a permanent magnet instead of field coils. The units are rated 28 v d-c input, and have an output of 350 v at 100 ma. The dynamotors are equipped with precision-fitted ball-

bearings to eliminate all end thrust and play occasioned by train motion and vibration.

This manufacturer also has available a new type hand-generator which has a maximum output of 100 watts. It is a permanent magnet



hand-generator which requires no outside electricity to operate. The cranks have been improved to prevent breakage due to operational leakage. A shatterproof unit enclosed with the meter, tells the operators when the output is being held to the correct value.

Carter Motor Corp., 1608 Milwaukee Ave., Chicago, Ill.

Radio Noise-Suppression Capacitor

COMPACT AND LIGHTWEIGHT Pyranol radio noise-suppression capacitors are especially designed to reduce noise voltage (particularly at higher frequencies) from generators, inverters, motors, and other equipment. The capacitors are of the thru-stud type with a terminal at each end. One line of a d-c or a-c power circuit can be fed through the unit, thereby reducing internal inductance and resistance, and in-

MONITOR with PANORAMIC

See a wide band- all at once

In the typical monitoring station—up to the present time—each received signal has required the active attendance of an operator and a receiver—the operator turning the dials ceaselessly and recording the signals on the air. With the aid of PANORAMIC RECEPTION, however, just one piece of equipment can do the work of many. Because PANORAMIC RECEPTION SHOWS ALL SIGNALS ON A GIVEN BAND OF THE RADIO FREQUENCY SPECTRUM SIMULTANEOUSLY, one operator can cover wider bands of the spectrum with more accuracy and less operator fatigue. Without dial manipulation, he can see immediately open channels and intermittent signals. Moreover, the patterns on the screen tell him the frequencies of the stations; their stability; their signal strength as they reach him; whether the station is AM, FM, or CW; and the type and extent of interference.

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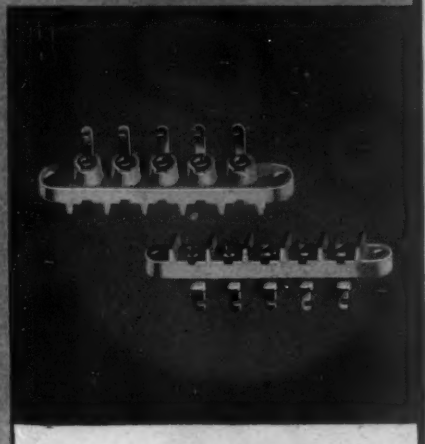
Application



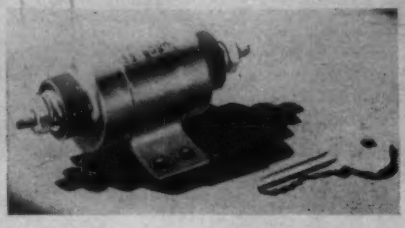
The No. 37105
Steatite Terminal Strip

• Another exclusive Millen "Designed for Application" product is the No. 37105 Steatite five-terminal strip. Lugs soldered as well as mechanically attached to floating screw machine units. Easy to mount with series of round holes for integral chassis bushings. Ideal answer to the "tropicalization" problem.

JAMES MILLEN MFG. CO., INC.

MAIN OFFICE AND FACTORY
MALDEN
MASSACHUSETTS

creasing filter efficiency for a given capacitance. The units can be mounted in any position and will operate over a temperature range of ±50 deg C. The capacitors are rated 0-100 amp, 250 v maximum



a.c. or d.c., 0.55 microfarad. They are designed to meet exacting vibration tests required by AAF specifications. Bulletin GEA-4308 contains complete information.

General Electric Co., Schenectady, N. Y.

Time Delay Relays

IN ORDER TO OPEN the main control circuit in case an added overload period exceeds a predetermined time interval on a line, Type TD8 accumulative time-delay relay may be used to add the time interval of momentary overload surges occurring in quick succession.

Also available is Type TD5 time-delay relay which will withstand momentary shocks without affecting the switch circuit. It has a cam-operated switch mechanism.

The R. W. Cramer Co., Inc., Centerbrook, Conn.

Split-Contact Switches

THESE DOUBLE-THROW, split-contact switches may be used to switch an operation from a d-c control to an a-c control. Two sets of contacts are mechanically interlinked but electrically isolated. Transfer action is a matter of a few milliseconds.

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RECORDING STUDIOS!
SCHOOLS!

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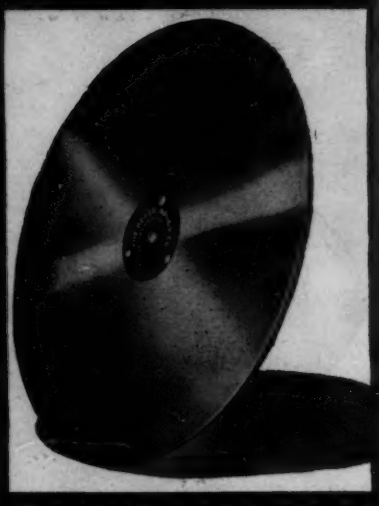

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The tributes paid to "Black Seal" discs by many leading engineers have been earned by distinguished service on the turntable. Your ears will recognize the difference in quality of reproduction, and the longer play-back life will prove the superiority of "Black Seal" construction. Choice of two weights — thin, flexible, interchangeable with aluminum, or medium weight — both with four holes.

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One battleship needs as many telephones as a city of 10,000

When U. S. warships go into action, telephone equipment transmits orders instantly, clearly.

For the huge battleship "Wisconsin," Western Electric supplied two separate telephone systems using equipment designed by Bell Telephone Laboratories.

1. *Sound powered telephone system* —with 2200 instruments connecting all battle stations. These battle phones operate on current generated by *the speaker's voice,* so damage to the ship's electrical power supply cannot interrupt communications.
2. *Battle announcing system* — with 20 transmitter stations and over 300 loudspeakers which broadcast orders in a giant voice.

All this for just one battleship! Aircraft carriers, cruisers, destroyers, submarines, merchant ships too must have telephone equipment.

Today Western Electric — long a pioneer and leader in the field of sound-transmission apparatus — is the *nation's largest producer of electronic and communications equipment* to aid our armed forces at sea, on land and in the air.

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New ATLAS Little GIANT
Model DR-12

Versatile is the word for Atlas Sound's latest creation, the DR-12 Little Giant (Bell diameter 7 in. Overall length 7½ in.) Its construction gives equally gratifying service when used for marine application, factory, police and other communications . . . a design that has proven itself more than equal to War's rigorous demands.

Write for detailed description.

ATLAS SOUND
CORPORATION
1449 39th Street Brooklyn, New York

The switches may also be used to control four isolated circuits by pairs, eliminating the use of relays and other isolating means from the circuit. The switches themselves have two contacts on both the normally open and normally closed side as shown in the accompanying illustration. Outside dimensions are the same as the manufacturer's basic SP switch. Catalog No. BZ-3YT describes pin-plunger types. Types D and S plunger designs are also available.

Micro Switch Corp., Freeport, Ill.

Capacitor Motors

THESE MOTORS (Type J-70) may be used for driving blowers in high ambient temperatures and for powering small control devices of all types. Units are rated 60 cycles, 115 v, single phase, 3400 rpm. They have a low temperature rise. Each

unit weighs 3 lb and measures 3$\frac{7}{16}$ in. in diameter, overall length 3$\frac{1}{8}$ in., shaft diameter $\frac{3}{16}$ in. Also available are motors which will deliver 1/25 hp and can be wound for 2 or 3 phase. Higher speeds and hp for 400-cycle applications are available.

Eastern Air Devices, Inc., 585 Dean St., Brooklyn 17, N. Y.

Flat Keying Relay

THE CHATTER HAS BEEN removed from Series 200 relays by a new improvement which consists of an energy-absorbing material, sealed within a contact-carrying cage. The compound used is not affected by age, oil or moisture. These improved relays have no bounce and will key up to 150 words per min, or 60 impulses per second. Input is 50 milliwatts. The armature of the units is mica insulated and is suitable for keying a 50-Mc r-f signal. Contacts will carry up to 2 amp.

Kurman Electric Co., 35-18 37th St., Long Island City, N. Y.

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All over the world Delco Radio products are in useful service. They prove daily that the name Delco Radio means dependability . . . dependable designs developed with care and imagination; dependable products built with craftsmanship and skill. In radio and electronic equipment, the name Delco Radio stands for engineering vision—manufacturing precision.

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NO VACUUM IMPREGNATION

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430 GC—TRANSPARENT...For very deep penetration. Forms very strong mechanical bond between wire and coil.

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ELIZABETH & NEPPERHAN AVES.
YONKERS 3, N. Y.

Potentiometers

THIS MANUFACTURER announces that they will again be able to supply potentiometers (Type N-103) made of non-substitute materials. Wartime restrictions changed the specifications for control shafts from aluminum to steel in standard sizes of 2½ in. lengths, and now the manufacturer is reverting again to aluminum shafts extending 3 in. from the end of a ⅜ in. bushing. Universal fluted mills which simplify filing and allow for all types of knobs will be used.

Centralab, 900 E. Keefe Ave., Milwaukee 1, Wis.

Rubber Latex Insulation

NUBUN IS THE NAME of a new synthetic rubber latex insulation for power and communication cable. It has improved electrical and physical characteristics for applications where replacement, servicing and space are important factors. Other features claimed for it include greater resistance to destructive forces, flexibility, impermeability to water and laminated construction. Nubun insulation is made from a special modification of buna S synthetic rubber.

United States Rubber Co. Rockefeller Center, New York, N. Y.

803 Pentode Tube

MASS PRODUCTION of Type 803 pentode tube for military and priority orders is now being done by Taylo Tubes, 2312 Wabansia Ave., Chi cago, Ill.

Phenolic Insulating Materia[1]

RESINOX No. 7934 is a new phenolic molding compound which may be used as an insulating medium in high-frequency apparatus. It has a low dielectric constant and power factor, low water and moisture absorption (0.03 percent under ASTM tests which call for 24-hour water immersion) and relatively high heat resistance. This new material is mica-filled and is based on a newly developed phenol - formaldehyde resin.

Monsanto Chemical Co., St. Louis 4, Mo.

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Unskilled operators will profile or accurately reproduce in smooth lines any design, number, letter, emblem, signature; on iron, brass, copper, aluminum, soft steels and all plastics. Here are some of its other uses . . .

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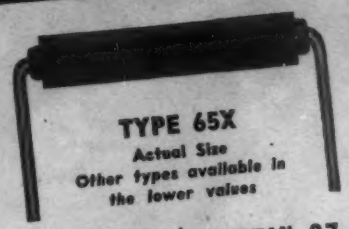
S.S.White RESISTORS
The "All-Weather" Resistors



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Actual Size
Other types available in the lower values

RESISTOR BULLETIN 37 GIVES FULL DETAILS . . .

It shows illustrations of the different types of S. S. White Molded Resistors and gives details about construction, dimensions, etc. A copy, with Price List will be mailed on request. Write for it — today.

WIDELY FAVORED because of NOISELESS operation, DURABILITY and fine PERFORMANCE in all climates . . .

STANDARD RANGE
1000 ohms to 10 megohms

NOISE TESTED

At slight additional cost, resistors in the Standard Range are supplied with each resistor noise tested to the following standard: "For the complete audio frequency range, resistors shall have less noise than corresponds to a change of resistance of 1 part in 1,000,000."

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MOLDED PLASTICS
MOLDED RESISTORS FLEXIBLE SHAFT TOOLS

NOW YOU CAN DO YOUR OWN
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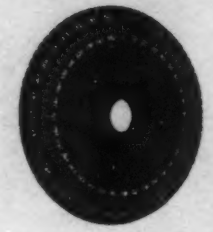

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★ Rogan's exclusive plastic branding process has been employed extensively to speed production of many important war plastics. The bakelite Azimuth Dial illustrated, is one example of Rogan's accuracy in branding. In fact, this important assignment was entrusted only to Rogan.

However, wartime demands for this service in some ordnance plants, have required the application on their own premises. So, Rogan engineers have arranged a method whereby anyone can do his own branding on plastics right in his own plant. Rogan will engineer each job completely and build all the necessary tools. Will provide clear, simple instructions that will permit anyone to do the job expertly. All you need do is to send us blue prints and other specific data, and we'll give you a quick cost and time estimate.

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NEW BOOKS

Automatic Control Engineering

By ED SINCLAIR SMITH, *research engineer, Eclipse-Pioneer Division of Bendix Aviation Corporation. McGraw-Hill Book Co., New York. 368 pages, price $4.00.*

THE AUTHOR has included the material necessary to enable anyone who has studied engineering to understand and apply the principles of control to any application or process. Considerable attention is given to terminology. Definitions are presented as adopted by the A.S.M.E. Division of Industrial Instruments and Regulators, German standards, and the 1941 Temperature Symposium.

To orient the reader, principles are enumerated which underlie the characteristics of meters and controllers, lags in plants, main components of controllers, steady-hunting performance, transient performance, and the application of regulators to plants. Although only a few pages deal specifically with electronic control principles, much of the non-electronic information is vitally essential to engineers seeking electronic solutions to control problems.—J.K.

• • •

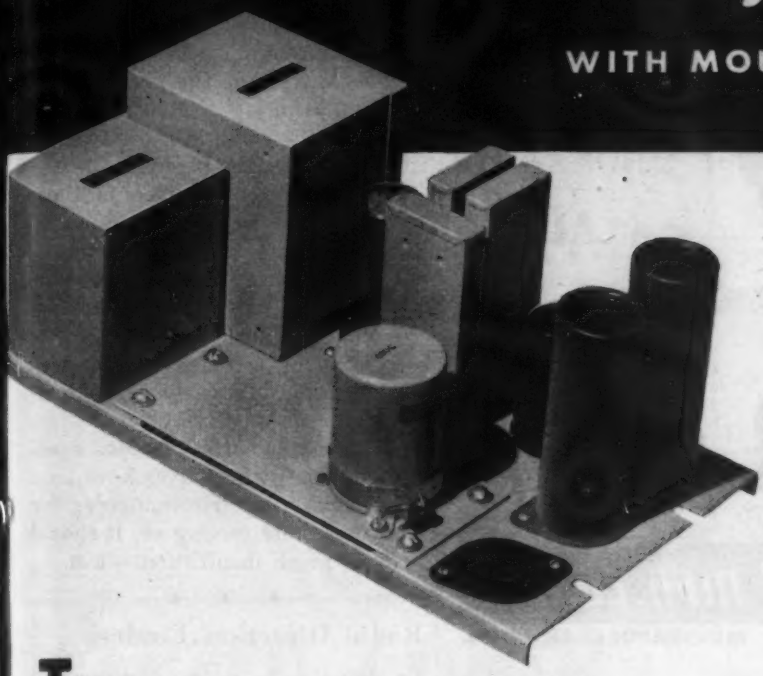
Beloved Scientist, life of Elihu Thomson

By DAVID O. WOODBURY, *Whittlesey House, New York. 1944. Price $3.50*

ALTHOUGH THE DIVIDING line between a scientist and an inventor is sometimes narrow, there can be no doubt about Elihu Thomson's place in the world—he was one of our great scientists. This story of David Woodbury's is not only a biography of a beloved scientist with an eager, creative mind which respected other minds; it is the story of the electric light, the arc lamp, the transformer, of dynamos and motors, electric welding, metering of electric current and voltage and power, of voltage regulators. For Elihu Thomson lived in an age of golden opportunity, as a contemporary (and often a competitor) of Edison, Brush, Bell, Westinghouse, Tesla, Röntgen, Marconi, Sprague, Lodge, Pupin. The book is also

102 SERIES *Amplifiers*

WITH MOUNTING ACCESSORIES



TYPE 102-A—Two stage—Fixed gain 55 db. Input impedance 30, 250 or 600 ohms; output impedance 600 ohms. Frequency response 30-16,000 Cycles ± .5 db. Power output + 26 VU with less than 1% harmonic content. Requires external power supply 275 Volts DC 30 M.A., and 6.3 Volts AC .75 Amps. When a 102 Series Amplifier is used in conjunction with a 101 Series Amplifier, the latter is capable of supplying the necessary power.

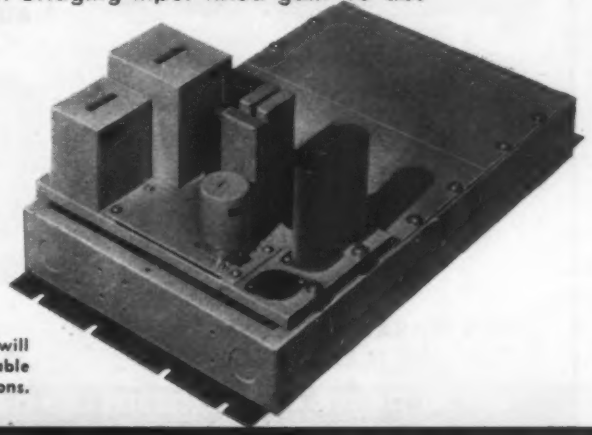
The 102 Series Amplifiers consist of four different amplifiers available simply by changing a small input panel on the master chassis. Except for the input panel, they all have the same transmission characteristics. Designed for the highest type audio service, they will meet frequency modulation requirements as to frequency response, power output vs. distortion and noise level.

TYPE 102-A as illustrated and described above.

TYPE 102-B—Three stage—Gain 95 db. Intended for high grade public address installations. Input stage electronic mixing.

TYPE 102-C—Three stage—Fixed gain 95 db.

TYPE 102-D—Two stage—Input impedance 600 ohms and bridging. Fixed gain 600 ohm input 61 db. Bridging input fixed gain 45 db.



The 3A Mounting Frame, requiring 10½ inches rack space, will accommodate up to THREE 102 Series Amplifiers and is suitable for wall mounting cabinet or rack and panel installations.

The Langevin Company

INCORPORATED

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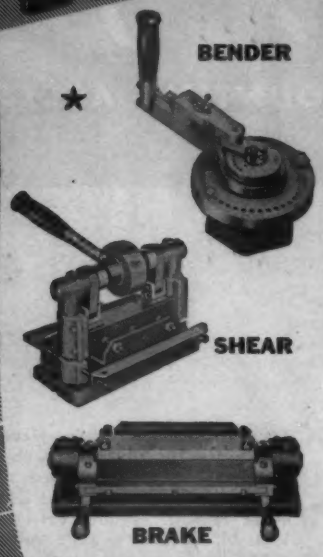

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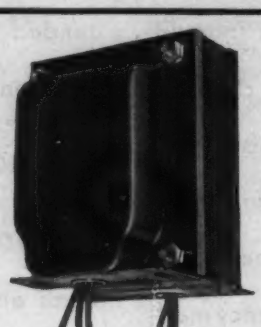
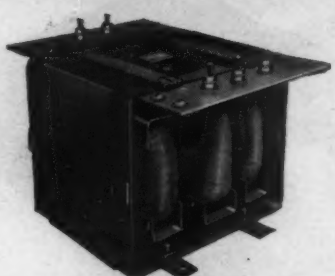
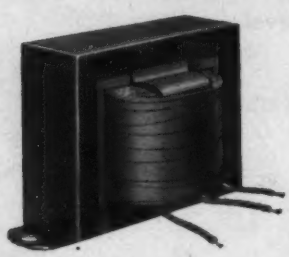


AUDIO TRANSFORMERS



HIGH LEAKAGE REACTANCE FILAMENT TRANSFORMERS



INTERSTAGE TRANSFORMERS

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the story of the foundation of the General Electric Company and of its early days; of Charles Coffin and E. W. Rice, Jr.

The book is also the story of many patent dogfights; and of a mercenary who seemed bent on making the days of the scientist-inventor Thomson unhappy. It is the story of imagination and ingenuity brought to service on the highest plane; of the great adventure of bringing electricity out of the laboratory and into the factory, the street car, the home.

Elihu Thomson's place in those great days is secure; he was interested in theory as well as practice; he worked with the utmost care, weighing, pondering, measuring. He knew what he was doing; he was humane; a social being as well as possessor of nearly seven hundred patents.

"Beloved Scientist" is good reading for those whose lives have been spent in the electric industry; for the youngsters coming on, it should provide much inspiration.—K.H.

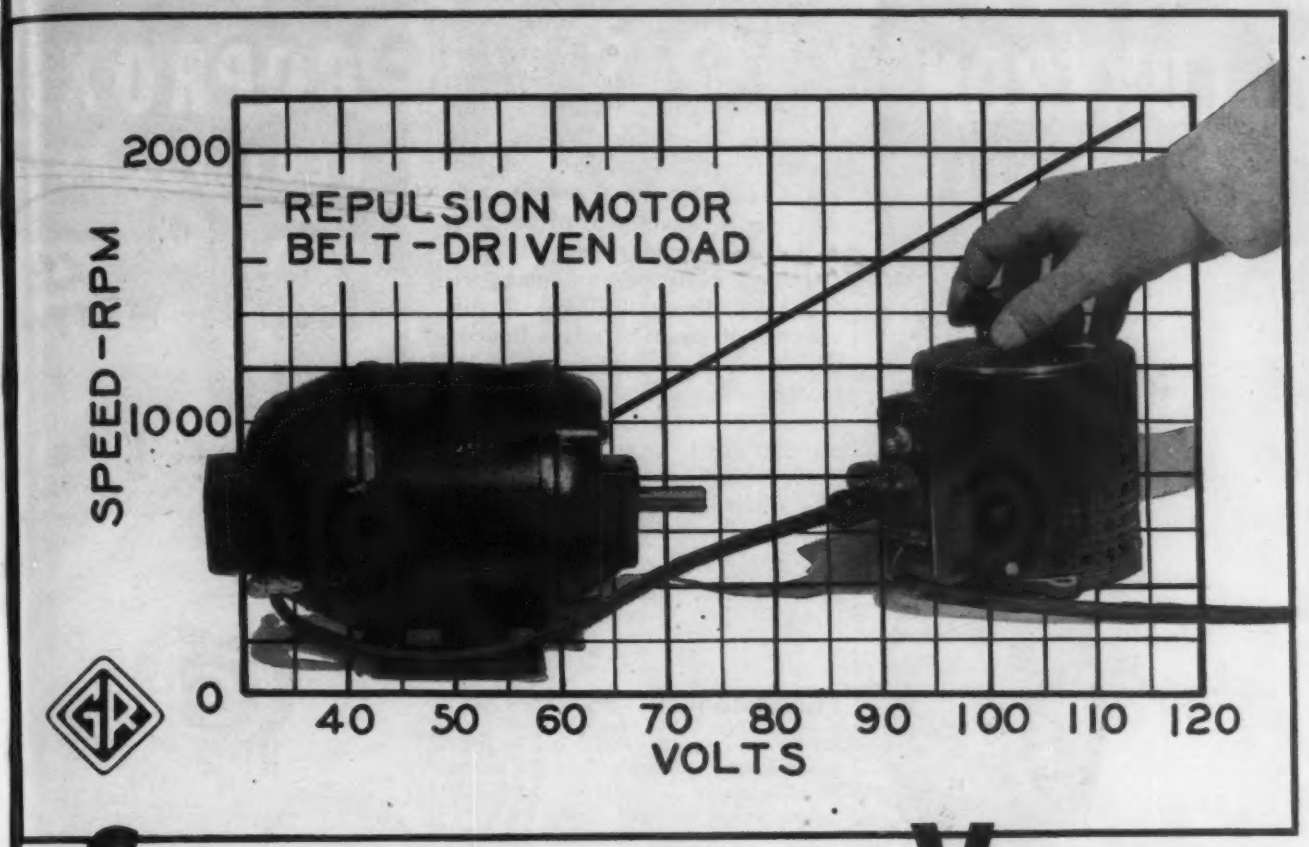
• • •

Radio Direction Finders

By DONALD S. BOND, *McGraw-Hill Book Co., New York 18, N. Y. 1944, 287 pages, 162 illustrations, price $3.00.*

THIS BOOK, the third in the McGraw-Hill communication series edited by Beverly Dudley, is the first published in this country exclusively on the subject of direction finders. The author, an experienced engineer in the field of direction finder design, writes specifically for electrical engineers and others having a broad engineering training and little if any experience in this particular specialized field. The author has made available in usable and organized form as much of the existing technical data on the development of direction finders as could be crammed into a volume whose size is not so great as to discourage a busy engineer in need of information. Application of the subject matter to specific problems is illustrated by means of examples worked out in the text.

The book starts out with a chapter giving general information and standard test procedures on direction finders. These data are tied in with data usually taken in making performance measurements on



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communications receivers, A goodly part of the material is in handbook form. Chapters on wave propagation, directive antenna systems, aural null direction finders, performance characteristics of loop input circuits, visual direction finders and radio navigational aids comprise the main body of the text. A rather complete description of the Mark I aircraft automatic direction finder is included in the chapter on visual direction finders. A mathematical appendix is included wherein the derivation of some of the formulas not derived in the text are to be found.

The many footnote references and bibliographies at the end of each chapter should facilitate further study on the part of those in need of additional information.—W.O.S.

• • •

Foundations of Wireless

By M. G. Scroggie. *Published by Iliffe & Sons, Ltd., Dorset House, Stamford St., London, S. E. 1., 4th ed., 1943, 358 pages, price 7s, 6d.*

A COMPLETE NEW EDITION of a well-known British basic textbook on radio.

Twenty-one chapters are provided and a simple listing of their headings indicates the logical treatment of the subject: an outline of broadcasting, elementary electrical notions, capacitance and inductance, alternating currents, a-c circuits, the tuned circuit, the triode valve, oscillation, the transmitter, detection, the single-valve receiver; reaction, radio-frequency amplification; screened valves, selectivity in the r-f amplifier, audio frequency and output stages, designing a receiver, the superheterodyne and its frequency changer, tuning circuits in the i-f amplifier, automatic controls, power supplies, radiation and aerials, and transmission lines. The preface explains mathematical formulas and symbols for readers having no technical training.

Although most of the terms used are standard for both British and American practice, there are some few variations that would be unfamiliar to readers on this side of the Atlantic. To overcome this there is a two-page appendix that lists terms and their equivalents, with distinctively American expressions printed in italics.—K.S.P.

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